

**MARINE MAMMAL RESEARCH IN THE GALAPAGOS ISLANDS:  
THE 1993-94 *ODYSSEY* EXPEDITION**

**Final Report**



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**Submitted to:**  
Galápagos National Park Service  
Charles Darwin Research Station

Puerto Ayora, Isla Santa Cruz,  
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10 November 1999

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## Introduction

The Ocean Alliance (formerly the Whale Conservation Institute) conducted marine mammal research in waters of the Galápagos Islands, Ecuador, between 5 March 1993 and 1 April 1994. The sailing vessel *Odyssey* served as the research platform used to study the ecology and behavior of the whales, dolphins and seals of the Galápagos during this study period. This Final Report summarizes the activities and results generated from this effort (a Preliminary Technical Report was submitted at the end of the expedition [Palacios, 1994]<sup>1</sup>). Many of the results have been published in the scientific literature. Portions of the data gathered, however, are still under analysis by different groups and will only slowly become part of the scientific literature, as is often the case with expeditions of this nature.

Activities additional to the scientific work of the Ocean Alliance included assisting Galápagos National Park Service (GNPS) and Charles Darwin Research Station (CDRS) scientists during a trip to eradicate introduced fire ants on Isla Marchena. Several interviews covering the purpose of the expedition were given to the local radio station. Also, groups of school children and persons representing a number of local organizations were invited aboard for educational tours during the stay of the *Odyssey* in the Galápagos.

## Overview of Objectives and Methods

The primary objective of the expedition was to conduct a year-round study of the social structure, behavior and occurrence patterns of the sperm whale around the Galápagos. A secondary objective was to collect data on the abundance, distribution patterns and habitat use of other marine mammal species present in the archipelago. To this effect, 17 cruises were completed during the 13-month study period. Methods for marine mammal searching involved visual surveys along the track line during the day and acoustic monitoring using a towed hydrophone array during both day and night periods. Environmental conditions were recorded every two hours along track, including sea-surface temperature, depth, sea state, cloud cover, wind speed and wind direction. Starting on 7 April 1993 the water column was sampled as schedule permitted, using a CTD (conductivity, temperature and depth) profiler to a nominal depth of 300 m.

Once detected, sperm whale groups were followed visually and acoustically for periods ranging from a few hours to a few days. During these follows, detailed behavioral notes were made, and photographs and genetic samples were taken for the identification of individuals. Some of the genetic samples were split and portions were used for analyses of pollutant loads. For sightings of other marine mammals, data collected included species identification, group size and behavioral notes. Acoustic recordings of the underwater vocalizations of several cetacean species were made.

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<sup>1</sup>Palacios, D.M. 1994. Preliminary technical report of the research on cetaceans conducted on board the R/V *Odyssey* in the Galápagos Islands, 5 March 1993 - 31 March 1994. Report submitted by the Whale Conservation Institute to the Charles Darwin Research Station, the Galápagos National Park Service, the Capitanía de Puerto Ayora, the Ministry of Defense of Ecuador, and the Director General of Fisheries, April 1994. 9pp.

To complement the second objective, data were also gathered on osteological remains of marine mammals that have been found on the islands. An inspection of the material available at the reference collection of the CDRS and other private collections in Puerto Ayora was conducted. Specimens housed in collections outside the Galápagos were also documented. Strandings of live cetaceans were investigated through interviews with persons who had first-hand accounts of the events or through published descriptions.

Samples of zooplankton, squid, fish, sperm whale feces and dead marine animals encountered at the surface were opportunistically collected on a few occasions, as an aid in the understanding of their local feeding ecology. These samples were identified and archived in appropriate collections.

## Results

The expedition covered the time period 5 March 1993 – 1 April 1994 (393 days). During this time 17 research cruises were completed, logging 205 days at sea and 31,390 km. Search effort for marine mammals during daylight hours amounted to 190 days and 15,251 km. Search effort per cruise varied between 539 and 1,513 km (mean=897 km, SD=303 km). On a daily basis, effort ranged between 7 and 164 km searched (mean=80 km, SD=31 km). Detailed information on cruise tracks and activities was presented to the CDRS and the GNPS at the end of each trip. The overall spatial coverage of the expedition is shown in Figure 1, as all track lines combined. The total searched portions are shown in Figure 2, as the combined on-effort segments along these track lines. A total of 1,879 entries for environmental conditions and 176 CTD stations were recorded. A temperature-salinity diagram for all the CTD profiles is presented in Figure 3. The spatial coverage of all the CTD stations is shown in Figure 4. There were 1,175 sightings of marine mammal groups (including 80 sperm whale groups). A summary of data collected during the cruises is presented in Table 1. Sighting information for each species is summarized in Table 2. Sighting locations are presented on a per-species basis in Figures 5-16 for the most frequently sighted species. Figure 17 summarizes CTD stations and search effort on a daily basis and Figure 18 shows the temporal evolution of sea-surface temperature (as measured along the track of the vessel), for the study period.

The photo-identification efforts during the *Odyssey* Expedition resulted in 341 sperm whale individuals being identified. A catalog of photographs of identified sperm whales has been prepared by Ocean Alliance research associate Erland Lettevall, in collaboration with Dalhousie University scientists Drs. Hal Whitehead and Jenny Christal. The catalog is kept at Dalhousie University. A total of 48 analog and DAT tapes of cetacean vocalizations were recorded during the study period. These tapes have been archived in the collection of the Ocean Alliance in Lincoln, Massachusetts.

Small samples of skin from sperm whales and blue whales were collected while following their groups. Whenever possible, the skin that is naturally shed by sperm whales was picked up from the surface of the water with a dip-net. There were 39 sloughed skin samples collected. In addition, 17 skin/blubber samples were taken using biopsy darts. Twenty-one of the sloughed skin samples and 16 of the biopsies (including two from blue whales) were shipped to Dr. Thomas Lyrholm of the Department of Zoology at Stockholm University, Sweden, for

genetic analyses. Subsamples of seven of these biopsies were shipped to Drs. Michael Moore and John Stegeman of Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, for pollutant analyses. The other 18 samples of sloughed skin and the remaining biopsy were deposited in the molecular genetics laboratory at the Marine Mammal Division, Southwest Fisheries Science Center, La Jolla, California, for future studies. Details of collection and distribution for all skin samples are reported in Table 3.

Biological samples collected at the surface along the ship's track included several specimens of one euphausiid, two squid and two fish species. Squid beaks found in sperm whale feces were also collected with a dip-net. In addition, tissues of a Bryde's whale and a green turtle were collected [see Brennan and Rodriguez (1994) in Appendix 1]. All these samples were identified and/or cataloged and have been deposited in appropriate collections, as detailed in Tables 3 and 4. A dead Cuvier's beaked whale found floating at the surface was collected and thoroughly dissected [see Palacios *et al.* (1994) in Appendix 1]. Samples preserved from this animal included its stomach contents, a number of internal and external tissues, and several ectocomensals attached to the trailing edge of its flukes (see Tables 3 and 4). The skull and mandibles are deposited in the CDRS reference collection. A dead bottlenose dolphin brought into Puerto Ayora by a fisherman was also dissected [see Lettevall *et al.* (1993) in Appendix 1]. Samples of soft tissues were collected but were later rendered unusable after a failure of the CDRS refrigerator. The skull and postcranial skeleton of this dolphin are deposited in the CDRS reference collection.

Documentation of marine mammal osteological remains found on the islands is presented in Appendix 2. Fifty-three specimens have been collected between 1923 and 1994, belonging to 12 cetacean species and one exotic otariid seal (documentation of specimens of the endemic Galápagos fur seal and sea lion is not included). Morphometric and meristic measurements were performed on 17 dolphin skulls belonging to four species. These data are included in Appendix 3.

## Discussion

Dr. Lyrholm recently completed a study of sperm whale social organization and genetic structure in a global context, including analysis of the skin samples that were sent to him from the Galápagos, for his doctoral dissertation. His results have been published in several papers, as listed in Appendix 1. The sperm whale subsamples sent to Drs. Moore and Stegeman were analyzed for dermal endothelial cytochrome P450 1A. Elevated values of cytochrome P450 1A are indicative of exposure to pollutants. Analysis of six of the biopsies yielded a mean semi-quantitative staining index (0-15) of  $0.8 \pm 1.3$  SD. Although this result is from an extremely small sample and it should be interpreted with caution, it is among the lowest values recorded when compared to analysis of biopsy samples from other species and localities [see Moore *et al.* (1995) in Appendix 1].

Of the 341 individual sperm whales identified through photographs, 83 (24.3%) had been photographed in previous expeditions to the Galápagos since 1985 by Dr. Whitehead and collaborators. The large majority of these identifications, however (258 individuals), corresponded to new individuals. The catalog of photo-identified individuals and associated data were incorporated in a study of the long-term patterns of associations in sperm whale social units

around the Galápagos [see Christal *et al.* (1998) in Appendix 1]. Mr. Lettevall has also been perfecting a technique to estimate body length in sperm whales from photographs. This has allowed him to determine the distribution of sex and age classes in animals photographed off the Galápagos during the *Odyssey* Expedition. He found that there were two peaks in calf abundance, one in June and one in February, and two peaks in mature male abundance, one in March-June and another one in October. These seasonal patterns in body length distribution suggest that sperm whales with at least two different reproductive schedules are present in Galápagos waters during the year. This observation lends weight to the hypothesis that northern and southern hemisphere sperm whale populations should be found near the equator during opposite times of the year [see Lettevall (1998) in Appendix 1].

A study of marine mammal abundance, distribution and habitat use around the Galápagos incorporating the search effort and oceanographic data collected during the *Odyssey* Expedition is currently underway by Daniel Palacios at Oregon State University (see publications by Palacios and collaborators in Appendix 1). As a point of interest, this study has already presented evidence that the productive waters of the western part of the archipelago are an important ground for endangered blue whales [see Palacios (1999) in Appendix 1].

## **Conclusion**

A wealth of data on Galápagos marine mammals and their habitat was gathered during the 1993-94 *Odyssey* Expedition. The samples and organisms collected will contribute to our understanding of marine diversity on local and global scales. Analysis and publication of these results will continue to ensure that the objectives of the expedition are fulfilled. Copies of all peer-reviewed publications that have resulted thus far have been sent to the CDRS for distribution among Ecuadorian organizations. A number of these papers have included a Contribution Number from the Charles Darwin Foundation for the Galápagos Islands and all of them have included the appropriate acknowledgements, as indicated in the Information for Visiting Scientists. We will continue to send reprints as papers appear in the literature. Appendix 1 is a complete list of all publications that have included results from the work by Ocean Alliance research associates in the Galápagos Islands.

## Acknowledgements

The 1993-94 *Odyssey* Expedition was conducted under permits MAG No. 051 IC and extension Oficio No. 1417-93 SNPG/GL from the Galápagos National Park Service. Export of samples was authorized through Oficios No. 280-94 SNPG, No. 281-94 SNPG and No. 653-94 SNPG/GL. The R/V *Odyssey* operated in Galápagos waters under permission from the Ecuadorian Ministry of Defense, the Ecuadorian Navy and the port captains of Puerto Ayora and Baltra. The Charles Darwin Research Station provided coordination and logistic support. TAME airlines provided reduced airfares between the Galápagos and continental Ecuador. The Ocean Alliance would like to thank GNPS personnel Arturo Izurieta, Felipe Cruz and Mikhael Bliemsrider, and CDRS personnel Chantal Blanton, Laura Chellis, Poly Robayo, Gayle Davis, Howard Snell and Heidi Snell for their contribution to the success of the expedition. A list of scientific crew, Ecuadorian students, naturalist guides and volunteers from the local community who participated in the R/V *Odyssey* cruises was included in the Preliminary Technical report. To all of them we would like to express our heartfelt appreciation.

Identification and archival of the biological samples was kindly provided by Kelly Robertson, Sarah Mesnick, Andrew Dizon and Robert Brownell at the Southwest Fisheries Science Center; Ed Brinton, Annie Townsend, William Newman and Cynthia Klepadlo at the Scripps Institution of Oceanography; Antonio Mignucci-Giannoni at the University of Puerto Rico; Sean Smith and Hal Whitehead at Dalhousie University; and Michael Moore at Woods Hole Oceanographic Institution.

Table 1. Summary of data collected during 17 cruises aboard R/V *Odyssey*, 5 March 1993 - 1 April 1994.

<b>Cruise No.</b>	<b>Cruise dates [dd/mm/yy]</b>	<b>Cruise duration [days]</b>	<b>No. days on-effort</b>	<b>Total distance [km]</b>	<b>Distance on-effort [km]</b>	<b>Total No. sightings</b>	<b>On-effort sightings</b>	<b>Off-effort sightings</b>	<b>No. SST records</b>	<b>No. CTD casts</b>
1	05/03/93 - 16/03/93	12	11	1481.63	981.68	94	92	2	116	0
2	21/03/93 - 30/03/93	10	10	1779.35	920.61	54	54	0	93	0
3	06/04/93 - 19/04/93	14	13	2320.73	1069.92	112	109	3	140	26
4	30/04/93 - 16/05/93	17	16	2935.03	1179.45	96	95	1	114	21
5	21/05/93 - 07/06/93	18	14	2311.91	894.56	50	44	6	116	14
6	15/06/93 - 28/06/93	14	11	1760.94	813.04	43	42	1	99	14
7	30/07/93 - 06/08/93	8	8	1202.18	743.89	58	58	0	88	27
8	14/08/93 - 20/08/93	7	7	1075.57	593.56	59	56	3	90	19
9*	10/09/93 - 12/10/93	7	7	1688.98	681.58	37	34	3	68	11
10	17/10/93 - 06/11/93	21	19	3020.15	1513.00	114	104	10	195	0
11	12/11/93 - 17/11/93	6	6	883.15	539.07	53	52	1	64	0
12	07/12/93 - 14/12/93	8	8	1191.84	710.02	77	75	2	84	3
13	21/12/93 - 31/12/93	8	8	1289.87	561.28	45	37	8	65	0
14	23/01/94 - 08/02/94	17	16	2944.34	1354.85	125	118	7	169	33
15	14/02/94 - 23/02/94	10	10	1207.54	539.31	34	32	2	100	6
16	01/03/94 - 16/03/94	16	16	2320.97	1330.68	83	80	3	167	2
17	21/03/94 - 01/04/94	12	10	1976.21	825.03	41	39	2	111	0
<b>Totals</b>		<b>205</b>	<b>190</b>	<b>31390.35</b>	<b>15251.52</b>	<b>1175</b>	<b>1121</b>	<b>54</b>	<b>1879</b>	<b>176</b>

\*Only 7 days were spent inside the study area during cruise No.9

Table 2. Summary of marine mammal sighting data collected during 17 cruises aboard R/V *Odyssey*, Galápagos Islands, 5 March 1993 - 1 April 1994.

<b>Sighting category / species</b>	<b>Total No. sightings</b>	<b>On-effort sightings</b>	<b>Off-effort sightings</b>	<b>Average group size (SD)</b>	<b>Range</b>
Common dolphin	139	137	2	166 (155.66)	8-900
Striped dolphin	31	31	0	57 (40.75)	13-175
Bottlenose dolphin	94	77	17	23 (29.03)	1-175
Risso's dolphin	19	19	0	22 (31.92)	4-140
Pilot whale	15	15	0	37 (46.64)	7-200
Killer whale	12	11	1	6 (2.28)	1-10
False killer whale	1	1	0	110	110
<i>Kogia</i> sp.	2	2	0	2 (0.71)	1-2
Cuvier's beaked whale	2	2	0	5 (2.12)	3-6
Beaked whale	8	8	0	4 (1.51)	1-6
Sperm whale	80	74	6	5 (7.70)	1-45
<i>Balaenoptera</i> sp.	204	193	11	1 (1.09)	1-7
Bryde's whale	47	45	2	2 (1.71)	1-8
Blue whale	8	8	0	2 (0.99)	1-4
Minke whale	3	3	0	1 (0)	1
Common & striped dolphin	3	3	0	75,30 (48.22,18.03)	40-130,15-50
Pilot whale & bottlenose dolphin	7	7	0	33,33 (14.42,10.78)	15-55,18-45
False killer whale & bottlenose dolphin	1	1	0	40,20	40,20
Unidentified dolphin	269	260	9	61 (102.40)	1-900
Unidentified cetacean	58	57	1	3 (4.48)	1-30
Galápagos fur seal	99	95	4	2 (1.60)	1-10
Galápagos sea lion	44	44	0	2 (2.11)	1-11
Unidentified otariid	29	28	1	2 (1.08)	1-4
<b>Totals</b>	<b>1175</b>	<b>1121</b>	<b>54</b>		

Table 3. Details of marine mammal tissue samples collected and their destination.

Species	Species name	Field No.	Cat. No.	Type	Latitude	Longitude	Date	Time	Destination
Sperm whale	<i>Physeter macrocephalus</i>	S3	N/A	sloughed	0.1350	-91.1917	18-Apr-93	9:20	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S4	N/A	sloughed	0.1350	-91.1917	18-Apr-93	12:00	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S8	N/A	sloughed	0.1150	-91.1783	18-Apr-93	12:00	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S5	N/A	sloughed	0.1350	-91.1917	18-Apr-93	12:15	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S6	N/A	sloughed	0.1233	-91.1550	18-Apr-93	12:55	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S7	N/A	sloughed	0.1233	-91.1550	18-Apr-93	13:15	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B9	N/A	biopsy	0.1200	-91.2233	18-Apr-93	17:10	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S10	N/A	sloughed	-0.5433	-91.8600	11-May-93	17:15	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S11	N/A	sloughed	-1.3667	-91.9000	13-May-93	10:30	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S12	N/A	sloughed	-1.3667	-91.9000	13-May-93	10:30	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B13	N/A	biopsy	-0.2133	-91.4317	14-May-93	17:05	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S17	N/A	sloughed	-0.4317	-91.6817	3-Jun-93	11:35	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B17	N/A	biopsy	-0.6767	-91.6717	3-Jun-93	15:30	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B19	N/A	biopsy	-0.2200	-91.8383	18-Jun-93	14:47	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B20	N/A	biopsy	-0.1467	-91.8250	18-Jun-93	16:20	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B21	N/A	biopsy	-0.5850	-91.8550	31-Jul-93	14:15	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S22	N/A	sloughed	-0.0350	-91.7567	15-Aug-93	11:43	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S25	N/A	sloughed	-0.0350	-91.7567	15-Aug-93	11:43	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B100	N/A	biopsy	0.1983	-89.8267	18-Oct-93	18:00	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B101	N/A	biopsy	0.1983	-89.8267	18-Oct-93	18:00	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B103	N/A	biopsy	-0.6233	-91.5333	26-Oct-93	7:45	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B104	N/A	biopsy	-0.5067	-91.6450	26-Oct-93	14:00	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B105	N/A	biopsy	-0.5017	-91.7250	26-Oct-93	14:35	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B106	N/A	biopsy	-0.8083	-91.8000	15-Nov-93	14:22	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B107	N/A	biopsy	-0.9483	-91.5517	29-Dec-93	18:15	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B108	N/A	biopsy	-0.6517	-91.7467	30-Dec-93	9:48	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S109	N/A	sloughed	-0.0200	-90.6467	5-Feb-94	15:10	Stockholm, Sweden

Table 3. Continued.

Species	Species name	Field No.	Cat. No.	Type	Latitude	Longitude	Date	Time	Destination
Sperm whale	<i>Physeter macrocephalus</i>	S110	N/A	sloughed	-0.0067	-90.6833	5-Feb-94	15:35	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S111	N/A	sloughed	0.0133	-90.7133	5-Feb-94	16:20	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S112	N/A	sloughed	0.0133	-90.7033	5-Feb-94	16:25	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S113	N/A	sloughed	0.0017	-90.7067	5-Feb-94	16:50	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S114	N/A	sloughed	0.0267	-90.7317	5-Feb-94	17:43	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B115	N/A	biopsy	-0.0500	-90.1167	6-Feb-94	11:25	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B116	N/A	biopsy	-0.0350	-91.1267	6-Feb-94	12:30	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B117	N/A	biopsy	-0.0350	-91.1267	6-Feb-94	13:00	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B118	N/A	biopsy	-0.0150	-90.9733	6-Feb-94	14:02	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S119	N/A	sloughed	-0.6667	-90.6217	15-Feb-94	14:30	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S120	N/A	sloughed	-0.0567	-90.6850	15-Feb-94	14:50	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S121	N/A	sloughed	-0.0567	-90.6850	15-Feb-94	14:50	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	S122	N/A	sloughed	0.1700	-91.2133	16-Feb-94	14:25	Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B123	N/A	biopsy	0.0950	-91.6317	21-Feb-94	11:25	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B124	N/A	biopsy	0.0950	-91.6317	21-Feb-94	11:25	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B125	N/A	biopsy	0.1600	-91.5917	21-Feb-94	12:55	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B126	N/A	biopsy	0.1667	-91.6017	21-Feb-94	14:45	WHOI, U.S.A. and Stockholm, Sweden
Sperm whale	<i>Physeter macrocephalus</i>	B127	Z8502	biopsy	0.0917	-91.5950	21-Feb-94	16:55	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S128	Z8484	sloughed	-0.7817	-91.8817	8-Mar-94	12:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S129	Z8485	sloughed	-0.7817	-91.8817	8-Mar-94	12:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S130	Z8486	sloughed	-0.7817	-91.8817	8-Mar-94	12:00	SWFSC, U.S.A.

Table 3. Continued.

Species	Species name	Field No.	Cat. No.	Type	Latitude	Longitude	Date	Time	Destination
Sperm whale	<i>Physeter macrocephalus</i>	S131	Z8487	sloughed	-0.7817	-91.8817	8-Mar-94	12:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S132	Z8488	sloughed	-0.7817	-91.8817	8-Mar-94	12:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S133	Z8489	sloughed	-0.7817	-91.8817	8-Mar-94	12:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S134	Z8490	sloughed	-0.8483	-91.8767	8-Mar-94	15:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S135	Z8491	sloughed	-0.8483	-91.8767	8-Mar-94	15:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S136	Z8492	sloughed	-0.8483	-91.8767	8-Mar-94	15:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S137	Z8493	sloughed	-0.8483	-91.8767	8-Mar-94	15:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S138	Z8494	sloughed	-0.8483	-91.8767	8-Mar-94	15:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S139	Z8495	sloughed	-0.8483	-91.8767	8-Mar-94	15:00	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S140	Z8496	sloughed	-0.8350	-91.9133	8-Mar-94	17:36	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S141	Z8497	sloughed	-0.8350	-91.9133	8-Mar-94	17:36	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S142	Z8498	sloughed	-0.8350	-91.9133	8-Mar-94	17:36	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S143	Z8499	sloughed	-0.8350	-91.9133	8-Mar-94	17:36	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S144	Z8500	sloughed	-0.8350	-91.9133	8-Mar-94	17:36	SWFSC, U.S.A.
Sperm whale	<i>Physeter macrocephalus</i>	S145	Z8501	sloughed	-0.8350	-91.9133	8-Mar-94	17:36	SWFSC, U.S.A.
Blue whale	<i>Balaenoptera musculus</i>	B26	N/A	biopsy	-0.1350	-91.7000	17-Aug-93	12:10	Stockholm, Sweden
Blue whale	<i>Balaenoptera musculus</i>	B27	N/A	biopsy	-0.1350	-91.7000	17-Aug-93	12:10	Stockholm, Sweden
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	N/A	Z8503	skin	0.1783	-92.0333	4-Mar-94	10:30	SWFSC, U.S.A.
Bryde's whale	<i>Balaenoptera edeni</i>	N/A	Z8504	muscle	-0.1467	-91.5467	25-Oct-93	8:30	SWFSC, U.S.A.
Green turtle	<i>Chelonia mydas</i>	N/A	Z8505	intestines	-0.1467	-91.5467	25-Oct-93	8:30	SWFSC, U.S.A.

WHOI = Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, U.S.A.

SWFSC = National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California, U.S.A.

Table 4. Details of specimens collected along the ship's track and their destination.

Specimen description	Species	Deposit
Euphausiids in surface swarm near feeding blue whales:	<i>Nyctiphanes simplex</i>	SIO Planktonic Invertebrate Collection No. PIC-960515-0001
Fishes dip-netted:	<i>Nomeus gronovii</i>	SIO Marine Vertebrate Collection No. SIO94-262
	<i>Myctophum nitidulum</i>	SIO Marine Vertebrate Collection No. SIO94-263
Whole squids picked up at the surface:	<i>Onychoteuthis banksii</i>	Sean Smith and Hal Whitehead, Dalhousie University, Nova Scotia, Canada
	<i>Bathyteuthis abyssicola</i>	Sean Smith and Hal Whitehead, Dalhousie University, Nova Scotia, Canada
Squid beaks dip-netted from sperm whale feces:	<i>Histioteuthis heteropsis</i>	Sean Smith and Hal Whitehead, Dalhousie University, Nova Scotia, Canada
	<i>Histioteuthis dofleini</i>	Sean Smith and Hal Whitehead, Dalhousie University, Nova Scotia, Canada
Cuvier's beaked whale stomach contents:	<u>squid*</u> : <i>Mastigoteuthis dentata</i>	SWFSC
	<i>Megalocranchia spp.</i>	SWFSC
	<i>Histioteuthis heteropsis</i>	SWFSC
	<i>Cranchia scabra</i>	SWFSC
	<i>Ommastrephes bartrami</i>	SWFSC
	<i>Liocranchia reinhardti</i>	SWFSC
	<i>Philidoteuthis spp.</i>	SWFSC
	unidentified species	SWFSC
	<u>crustaceans</u> : <i>Gnautophausia ingens</i>	SIO Planktonic Invertebrate Collection No. PIC-960515-0002
	<i>Acanthephyra</i> sp.	SIO Planktonic Invertebrate Collection No. PIC-960515-0002
	<u>others</u> : Many squid spermatophores	Not preserved
	Many squid eye lenses	Not preserved
Cuvier's beaked whale ectocomensals:	<i>Xenobalanus globicipitis</i>	SIO Benthic Invertebrate Collection No. C-9825

SIO = Scripps Institution of Oceanography, University of California San Diego, La Jolla, California, U.S.A.

SWFSC = National Marine Fisheries Service, Southwest Fisheries Science Center, La Jolla, California, U.S.A.

\*some beaks were sent to Sean Smith and Hal Whitehead, Dalhousie University

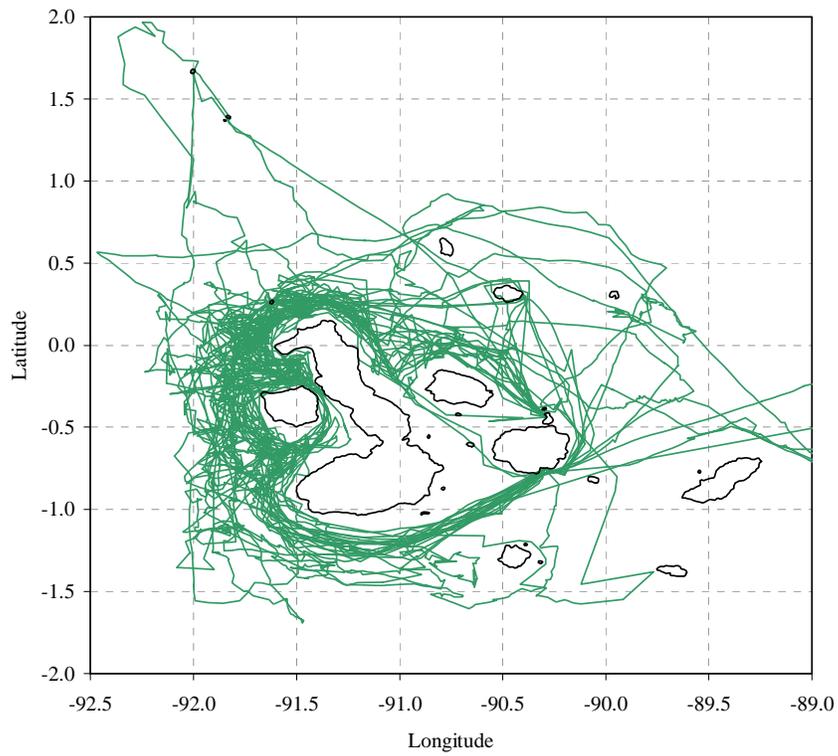


Figure1. Tracklines for 17 cruises aboard R/V *Odyssey*, 5 March 1993 - 1 April 1994

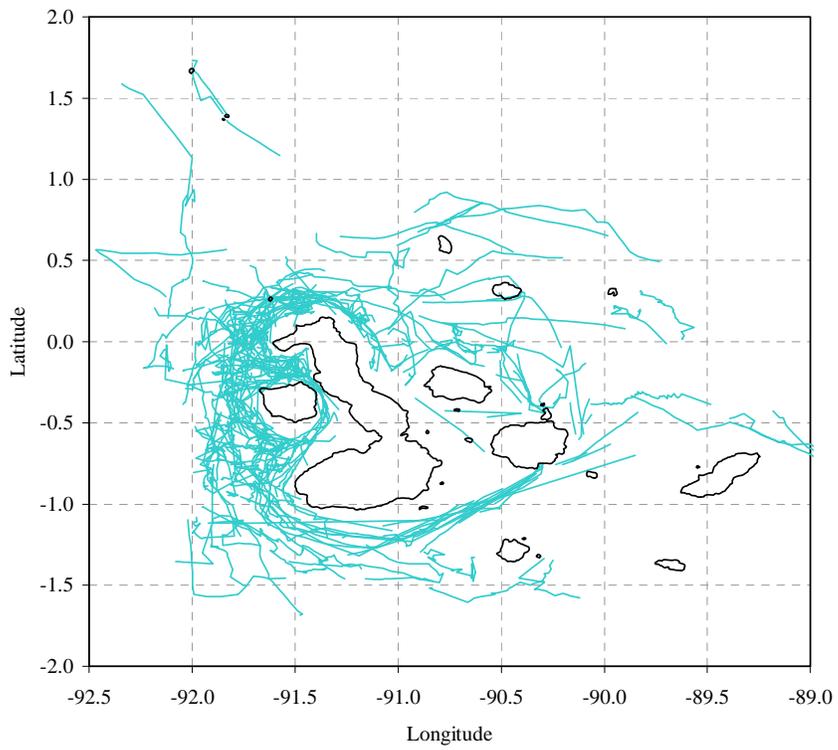


Figure 2. On-effort segments for 17 cruises aboard R/V *Odyssey*, 5 Mar 1993 - 1 Apr 1994

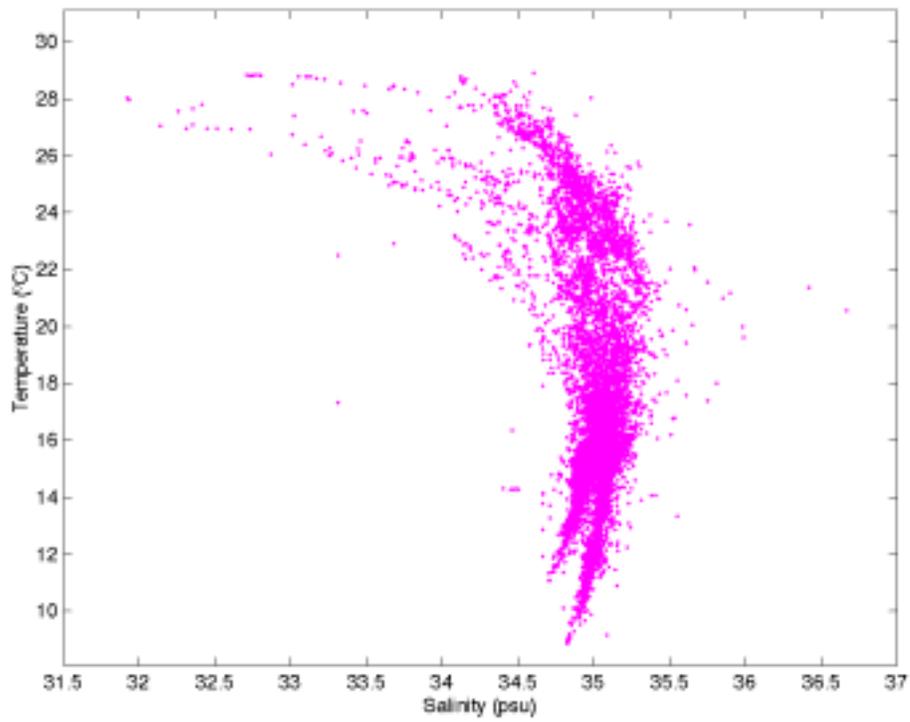


Figure 3. Temperature-salinity diagram for 176 CTD casts, 7 April 1993 - 3 March 1994.

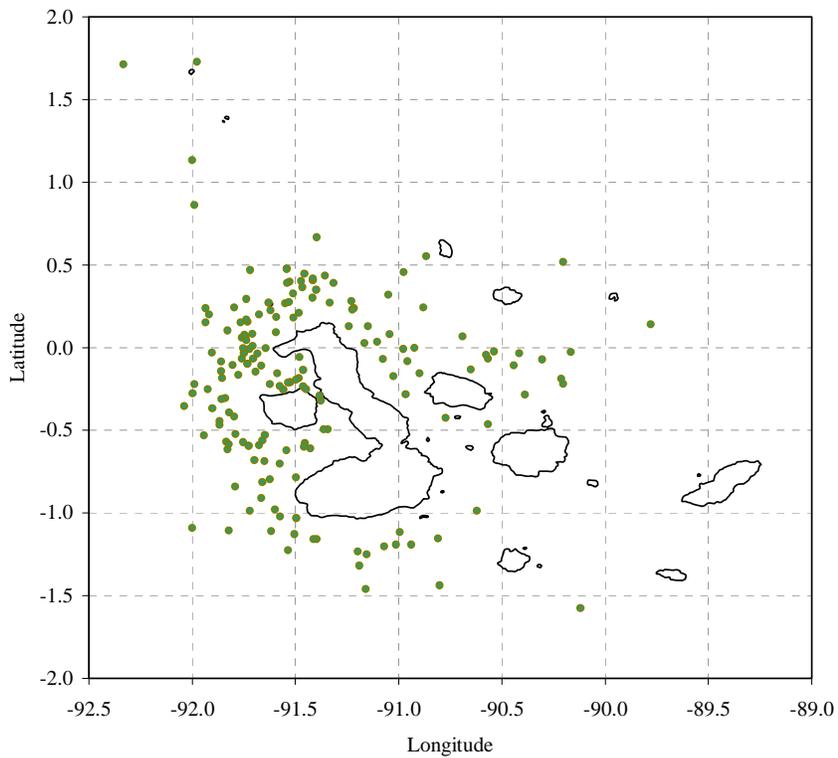


Figure 4. Location of 176 CTD stations, 7 April 1993 - 3 March 1994.

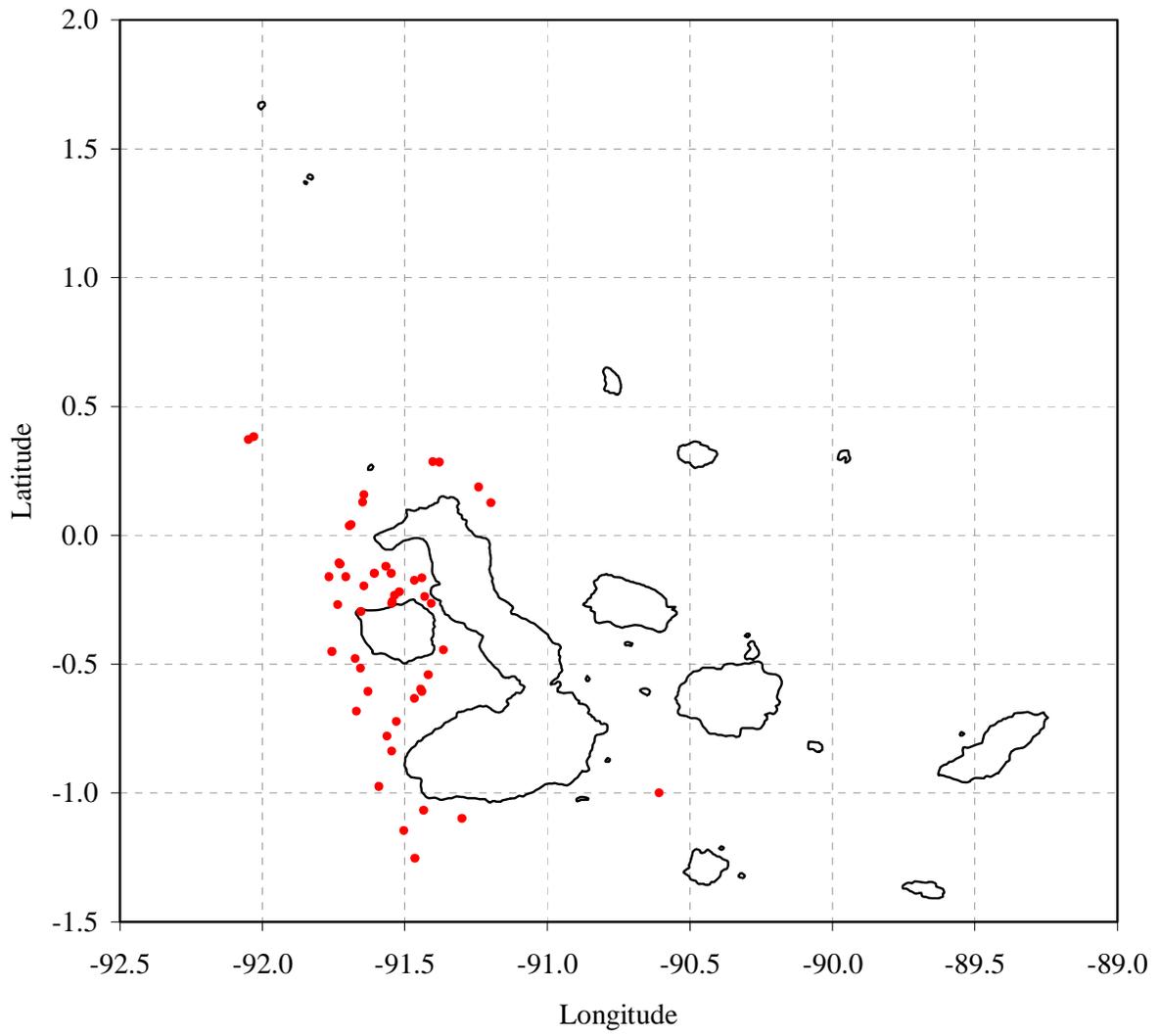


Figure 5. Bryde's whale sightings (n=47)

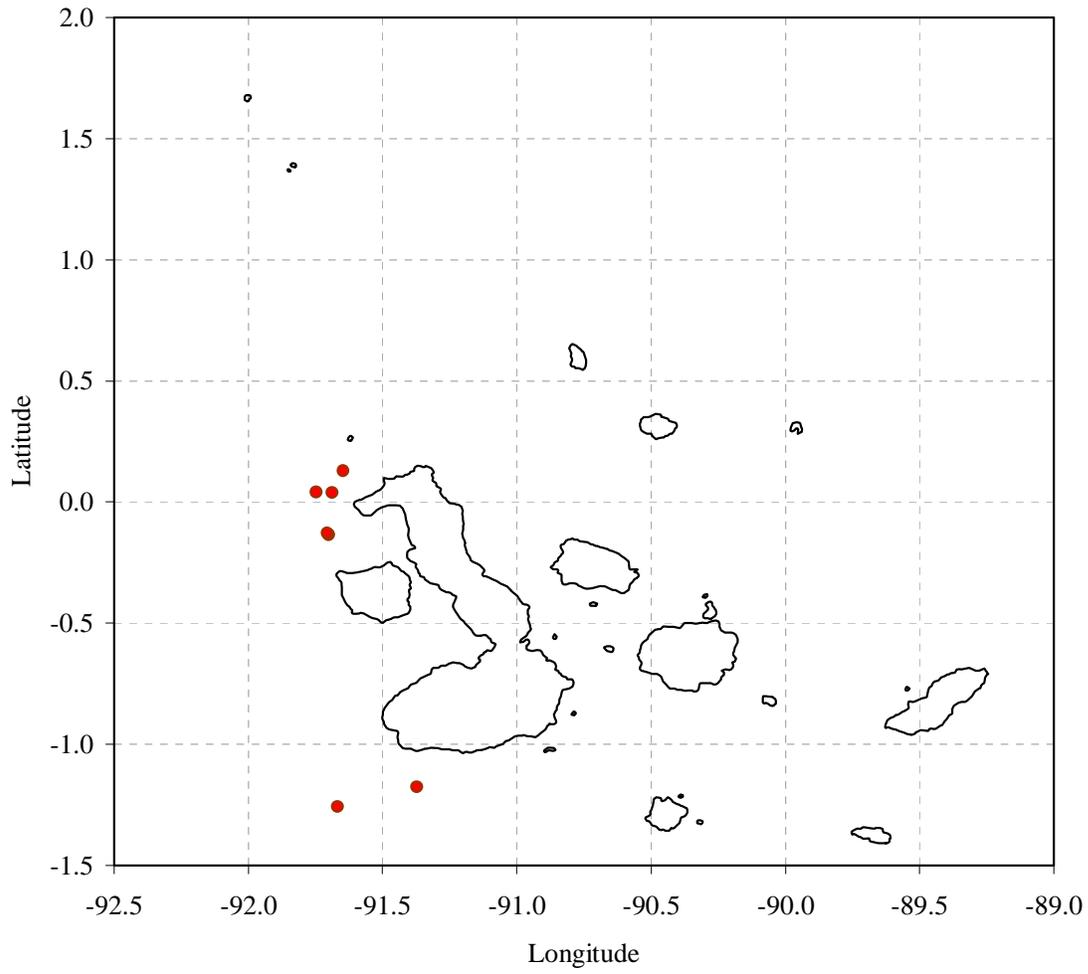


Figure 6. Blue whale sightings (n=8)

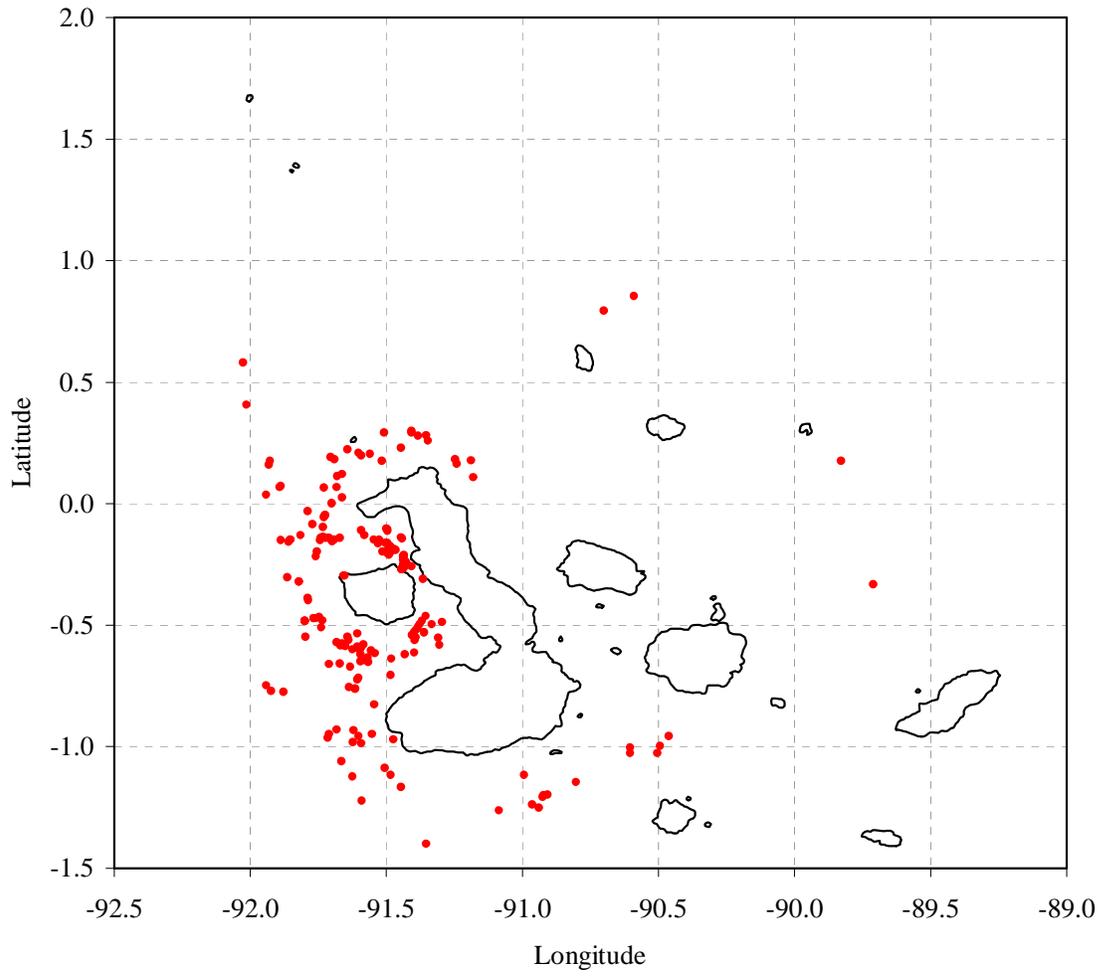


Figure 7. *Balaenoptera* sp. sightings (n=204)

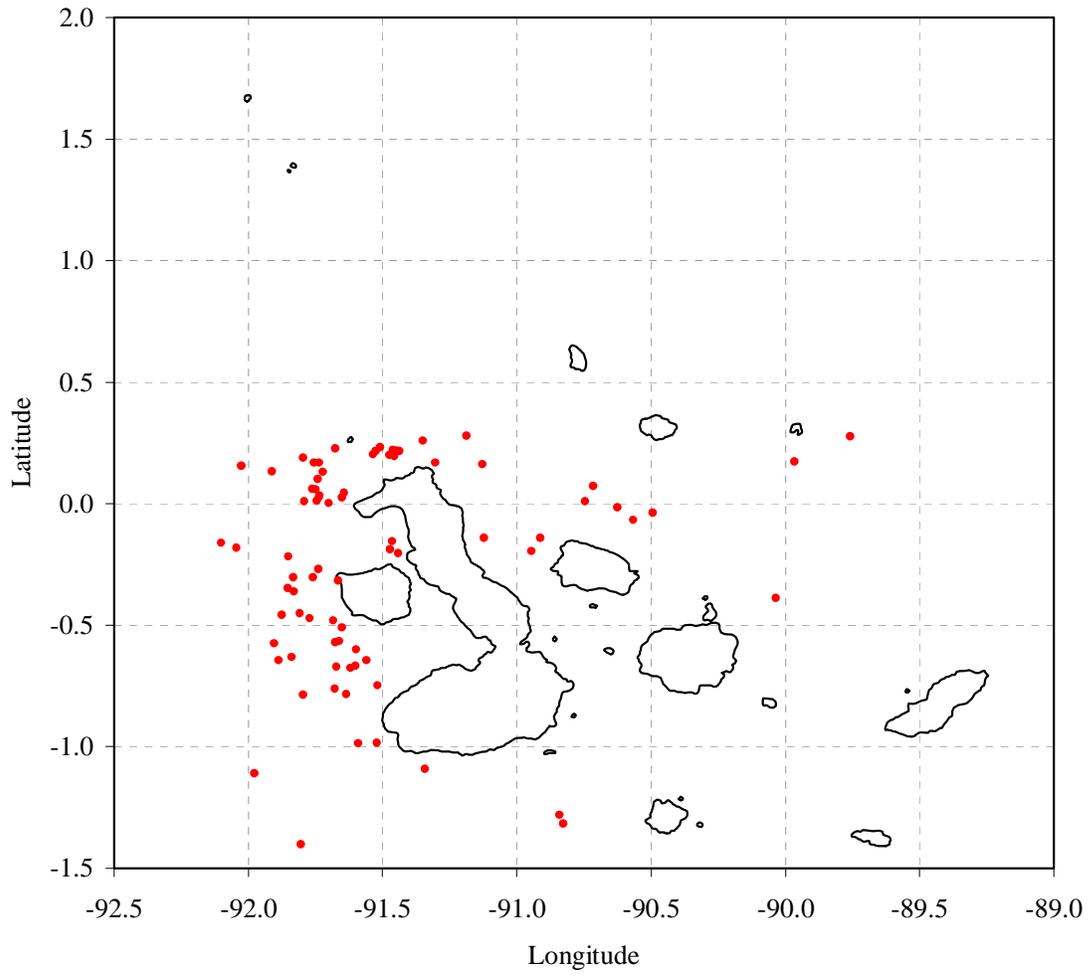


Figure 8. Sperm whale sightings (n=80)

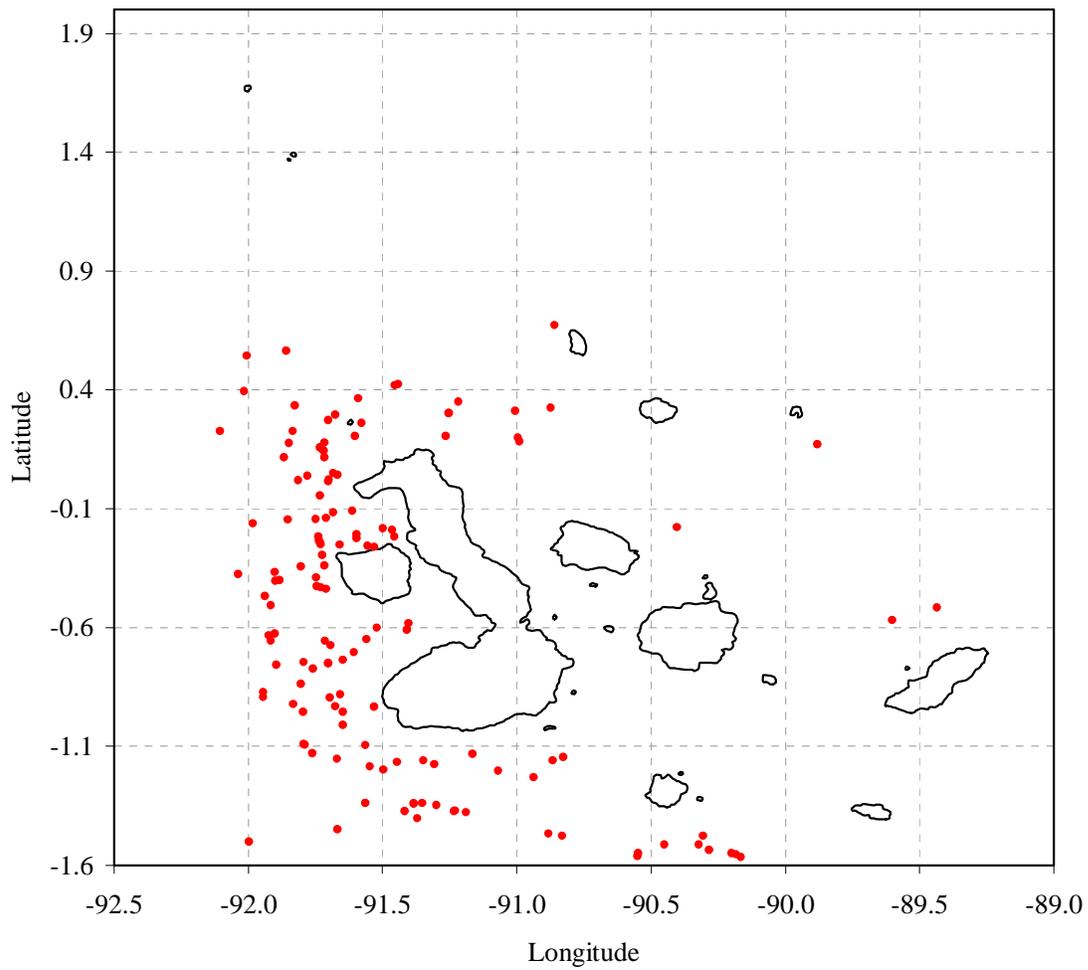


Figure 9. Short-beaked common dolphin sightings (n=139)



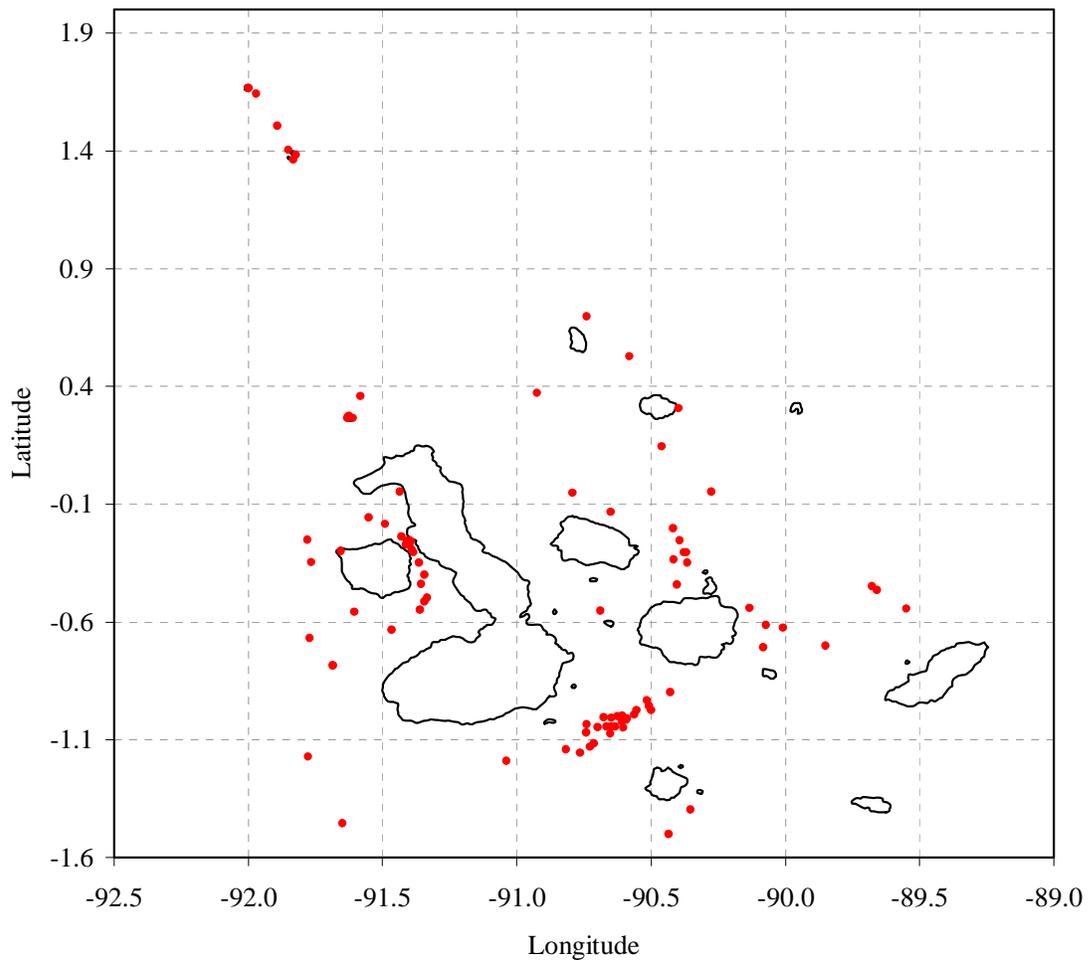


Figure 11. Bottlenose dolphin sightings (n=94)

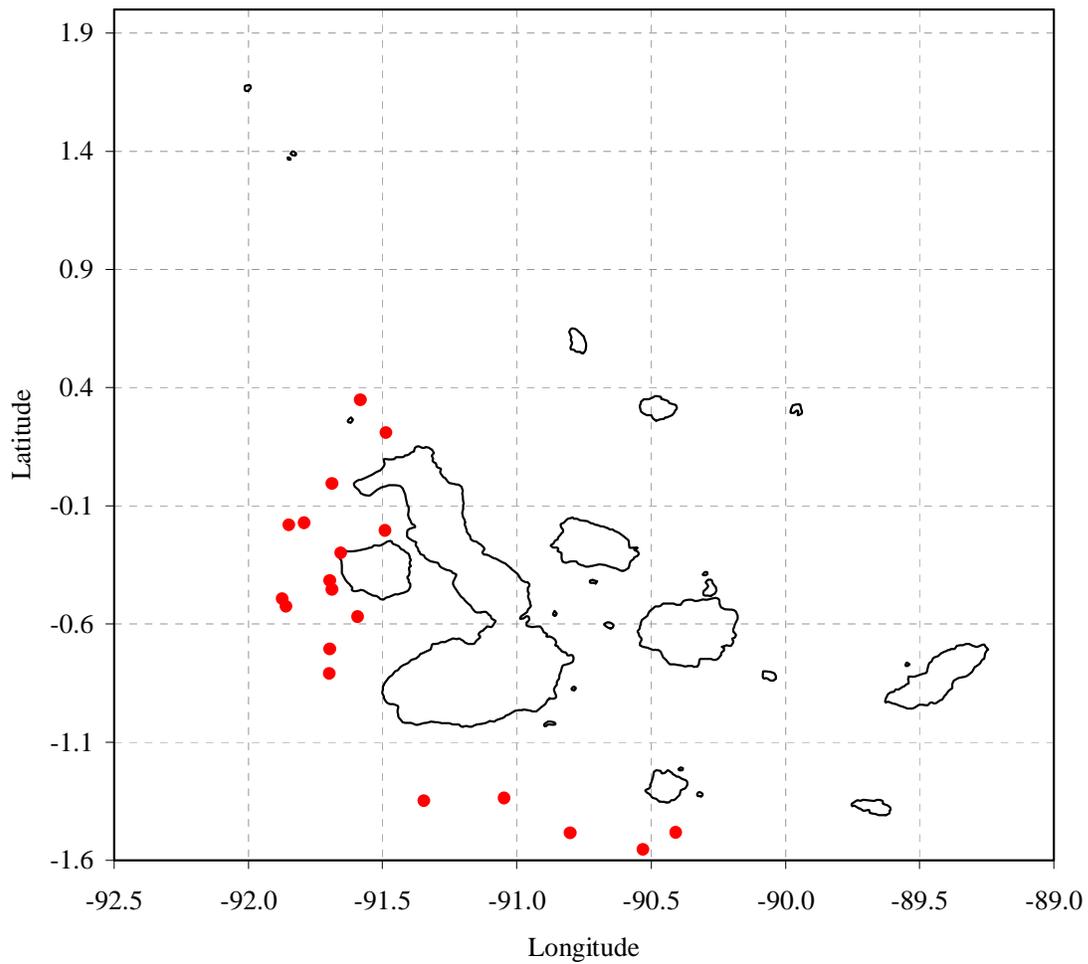


Figure 12. Risso's dolphin sightings (n=19)

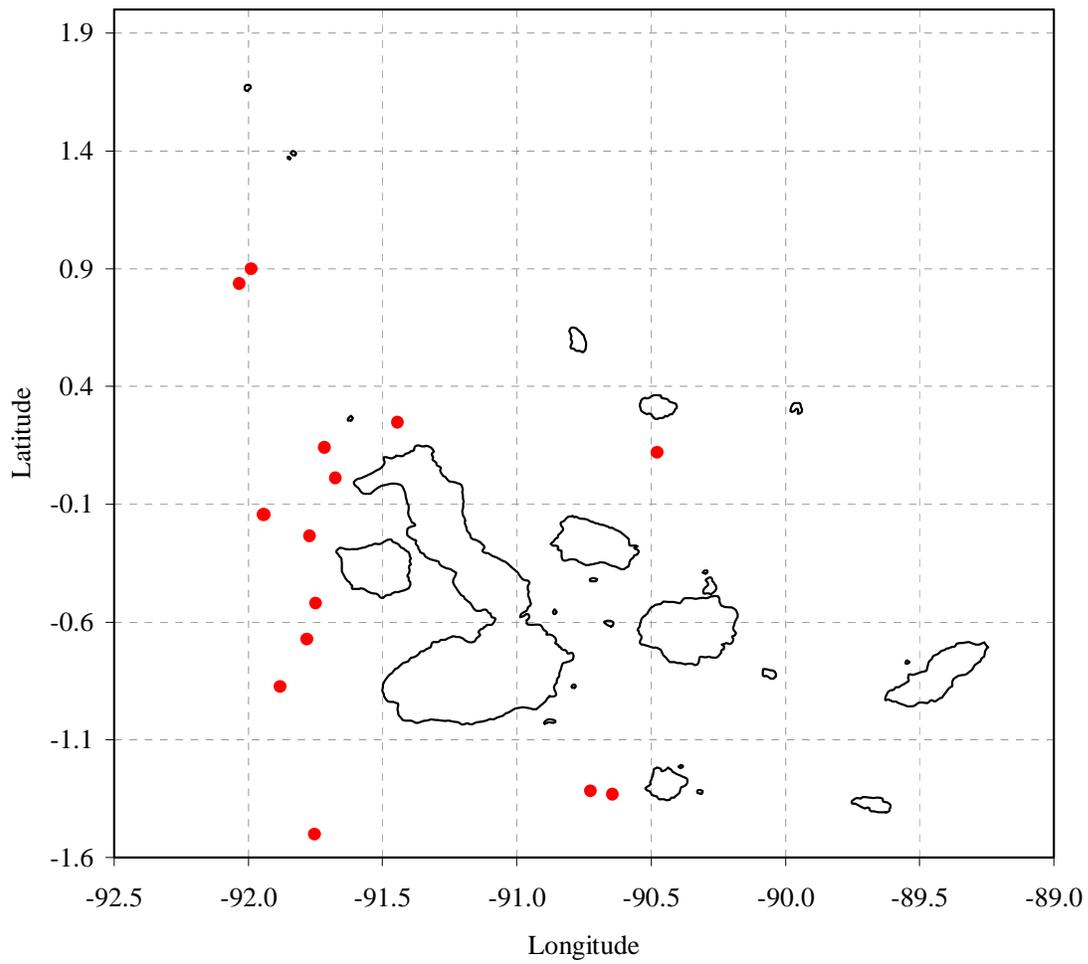


Figure 13. Short-finned pilot whale sightings (n=15)

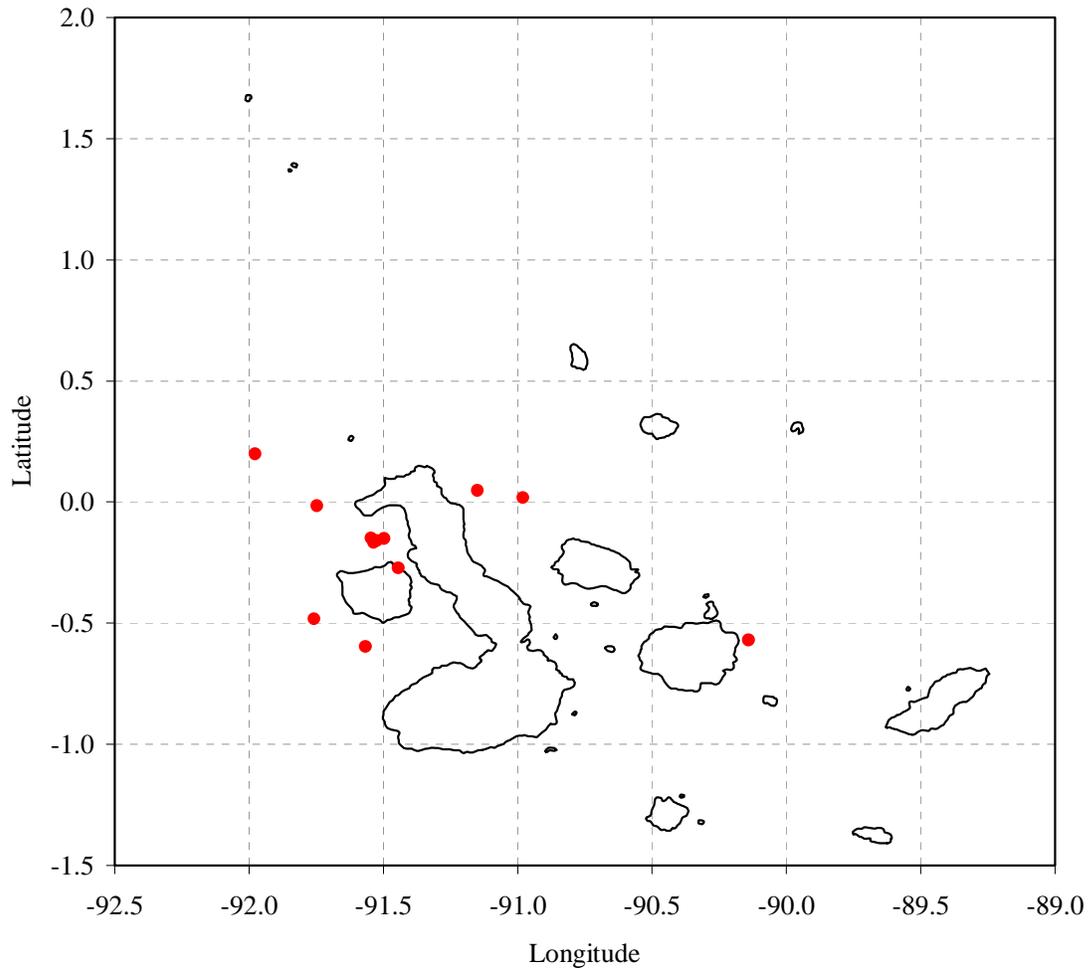


Figure 14. Killer whale sightings (n=12)

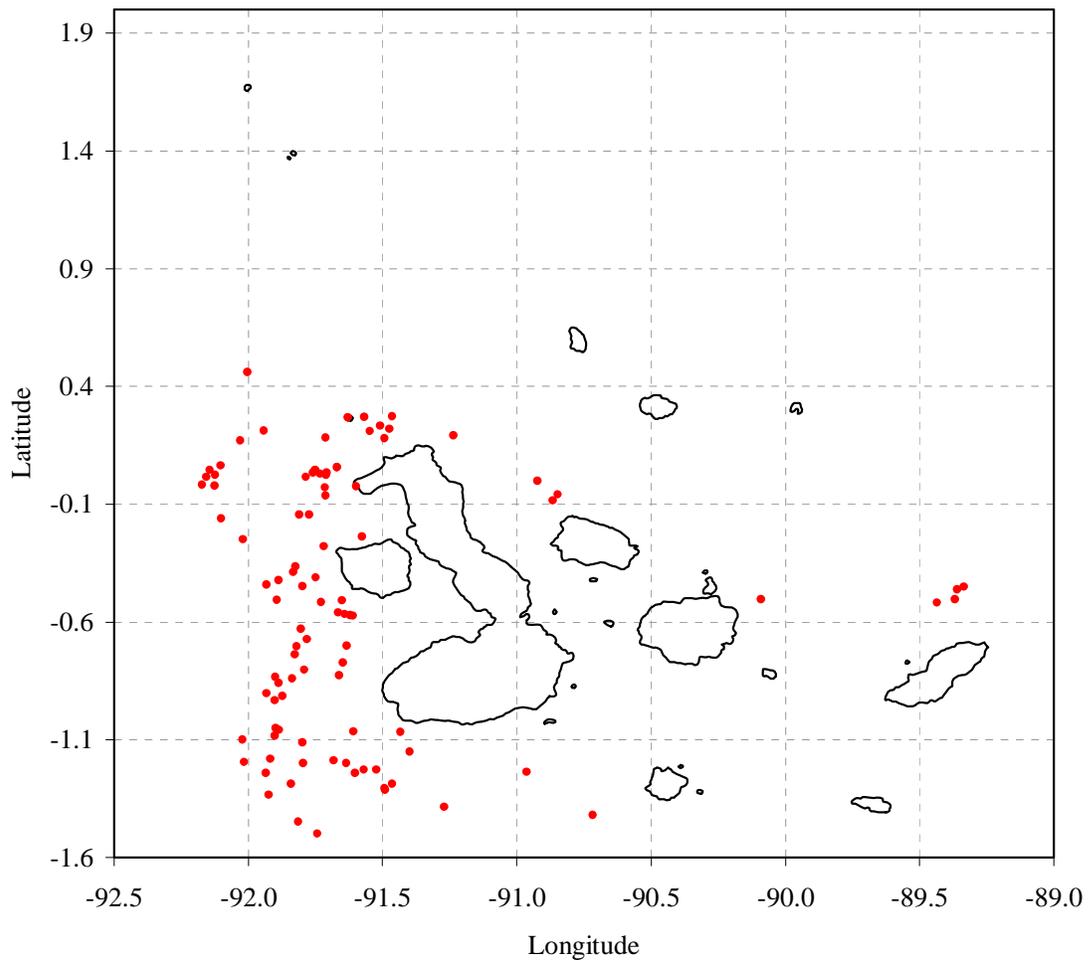


Figure 15. Galápagos fur seal sightings (n=99)

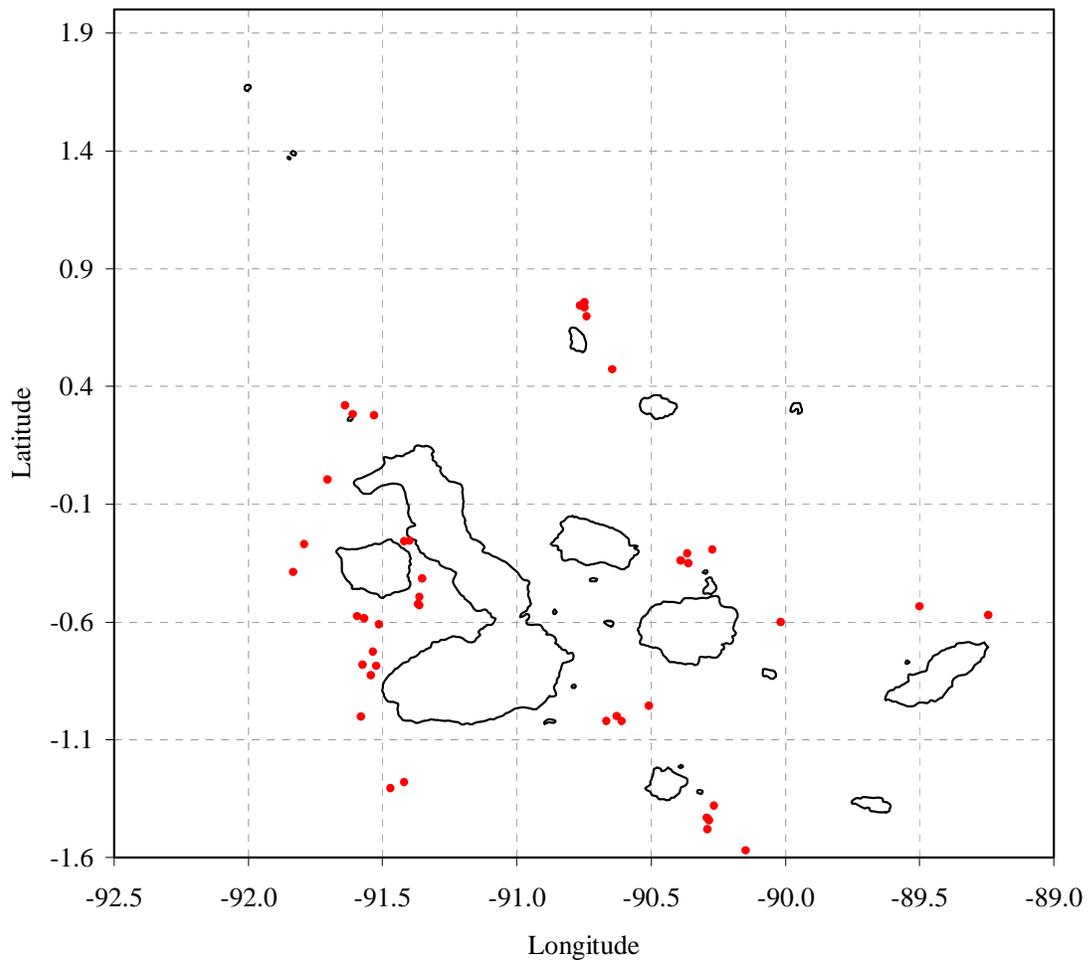


Figure 16. Galápagos sea lion sightings (n=44)

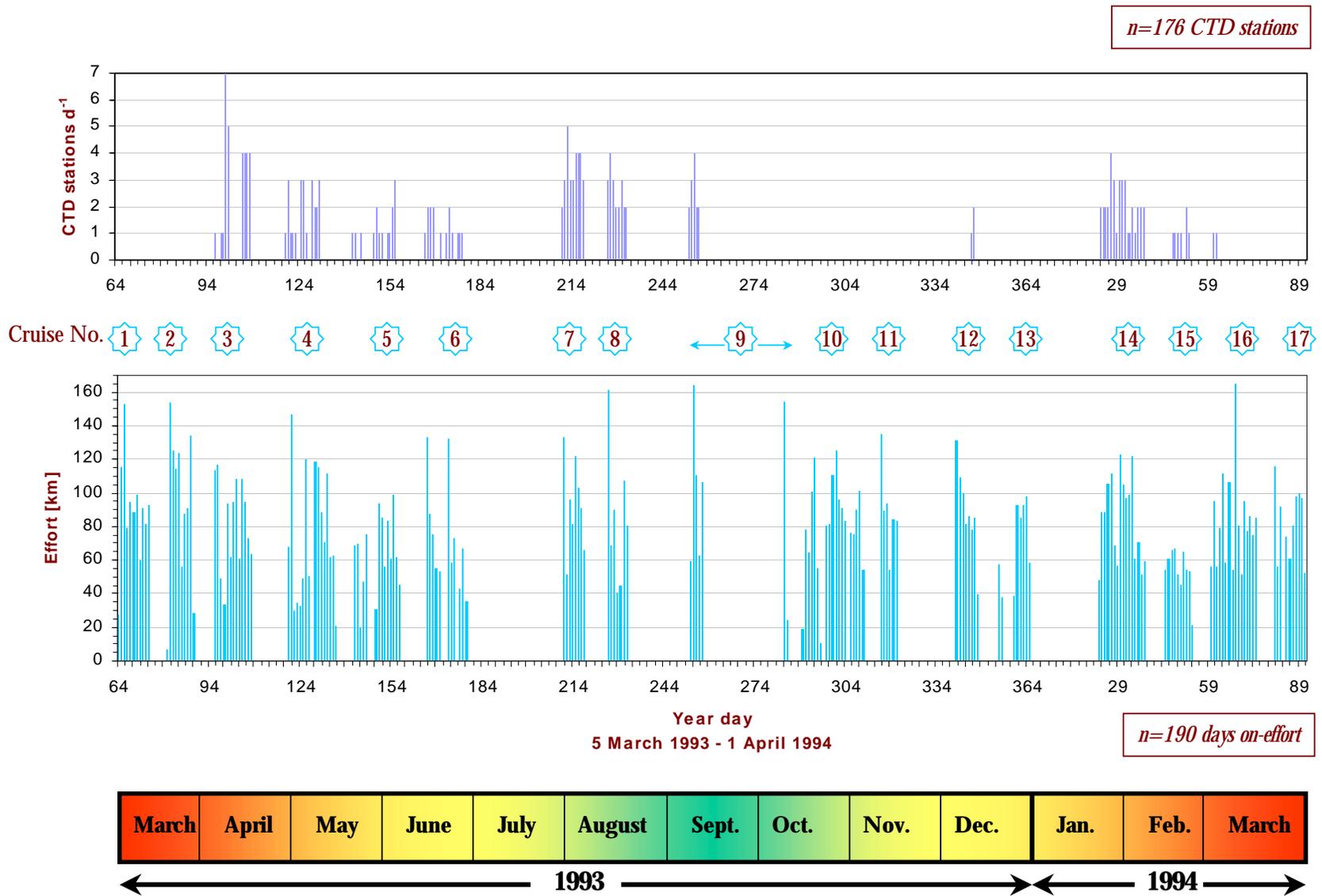


Figure 17. Distribution of daily CTD stations and marine mammal search effort during the study period.

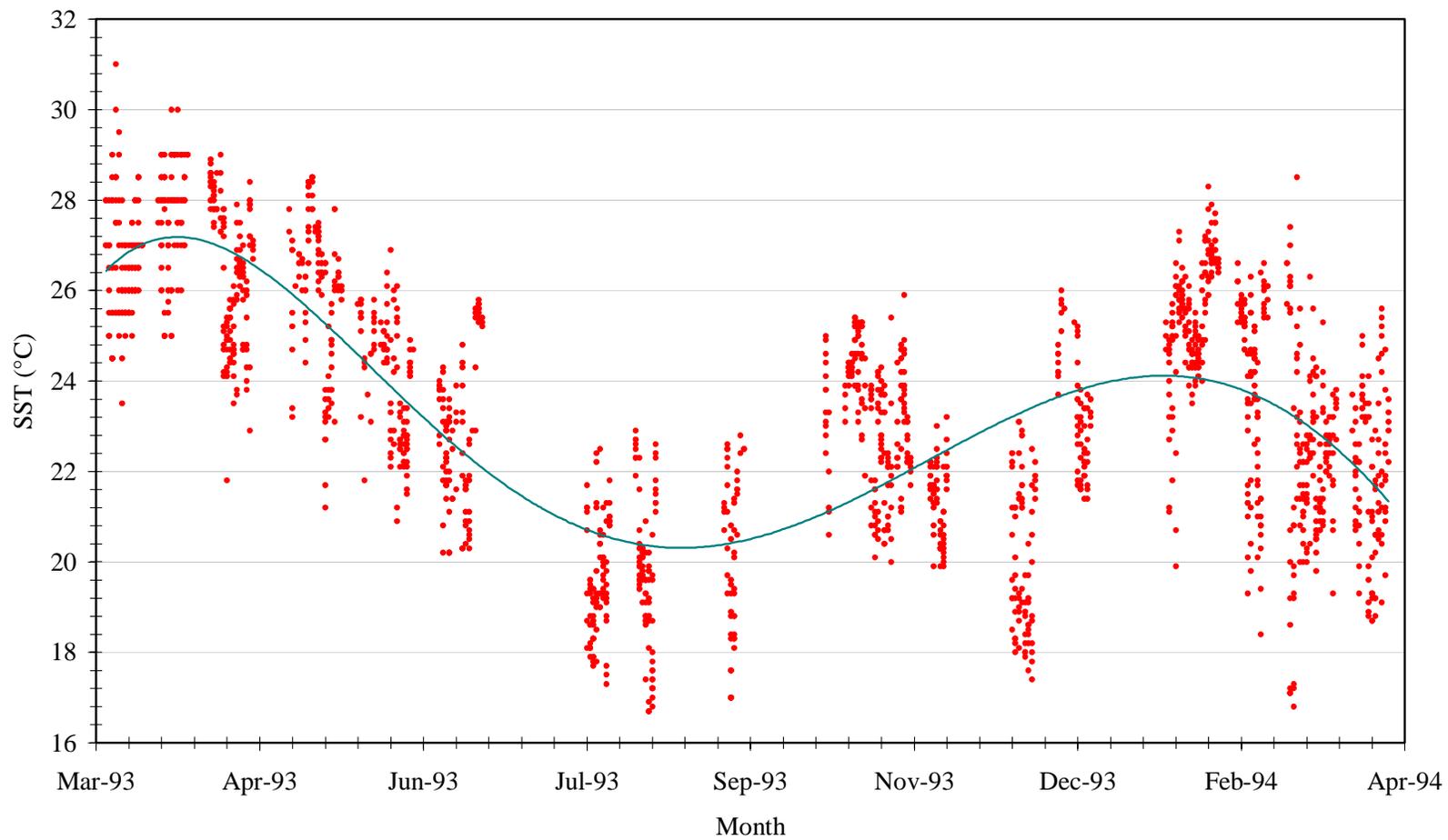


Figure18. Along-track sea-surface temperature for 17 cruises aboard R/V *Odyssey*, 5 March 1993 - 1 April 1994. The fitted curve represents the seasonal cycle computed by least squares regression onto annual plus semi-annual harmonics and a constant offset.

## Appendix 1

### SCIENTIFIC PUBLICATIONS THAT HAVE RESULTED FROM THE WORK OF OCEAN ALLIANCE RESEARCH ASSOCIATES IN THE GALAPAGOS

(in alphabetical order):

- Brennan, B.** and **P. Rodriguez.** 1994. Report of two orca attacks on cetaceans in Galápagos. *Noticias de Galápagos* 54:28-29.
- Christal, J., H. Whitehead and **L. Lettevall.** 1998. Sperm whale social units: variation and change. *Canadian Journal of Zoology* 1431-1440.
- Day, D.** 1994. List of cetaceans seen in Galápagos. *Noticias de Galápagos* 53:5-6.
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- Lyrholm, T.** and U. Gyllensten. 1998. Global matrilineal population structure in sperm whales as indicated by mitochondrial DNA sequences. *Proceedings of the Royal Society of London B* 265:1679-1684.
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- Muñoz-Hincapié, M.F., D.M. Mora-Pinto, **D.M. Palacios,** E.R. Secchi and A.A. Mignucci-Giannoni. 1998. First osteological record of the dwarf sperm whale in Colombia, with notes on the zoogeography of *Kogia* in South America. *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales* 22(84):433-444.
- Palacios, D.M.** 1995a. Re-identification of three dolphin skulls in the Museum of the Charles Darwin Research Station. *Noticias de Galápagos* 55:6-8.
- Palacios, D.M.** 1995b. Cetacean remains and strandings in the Galápagos Islands. Pages 27-29 in A.H. Kopelman, ed. *Proceedings of the 1995 Northeastern Regional Stranding Network Conference*, 28-30 April 1995, Riverhead, NY, USA.
- Palacios, D.M.** 1996a. Earlier observations of presumed Galápagos sea lions, *Zalophus californianus wollebaeki*, from coastal Ecuador. *Marine Mammal Science* 12(3):497.
- Palacios, D.M.** 1996b. On the specimen of the ginkgo-toothed beaked whale, *Mesoplodon ginkgodens*, from the Galápagos Islands. *Marine Mammal Science* 12(3):444-446.

- Palacios, D.M.**, F. Félix, L. Flórez-González, J.J. Capella, D. Chiluiza and B.J.M. Haase. 1997. Sightings of Galápagos sea lions (*Zalophus californianus wollebaeki*) on the coasts of Colombia and Ecuador. *Mammalia* 61(1):114-116.
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- Palacios, D.M.**, P. Rodríguez, B. Brennan and K. Marshall. 1994. Notes on the Cuvier's beaked whale (*Ziphius cavirostris*) with observations of a dead specimen. *Noticias de Galápagos* 54:29-31.
- Palacios, D.M.** and **D. Day**. 1995. A Risso's dolphin (*Grampus griseus*) carrying a dead calf. *Marine Mammal Science* 11(4):593-594.
- Palacios, D.M.** and B.R. Mate. 1996. Attack by false killer whales (*Pseudorca crassidens*) on sperm whales (*Physeter macrocephalus*) in the Galápagos Islands. *Marine Mammal Science* 12(4):582-587.
- Pitman, R.L., **D.M. Palacios**, **P.L.R. Brennan**, **B.J. Brennan**, K.C. Balcomb, III and T. Miyashiyu. 1999. Sightings and possible identity of a bottlenose whale in the tropical Indo-Pacific: *Indopacetus pacificus*? *Marine Mammal Science* 15(2):531-549.
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- Whitehead, H., S. Waters and **T. Lyrholm**. 1991. Social organization of female sperm whales and their offspring: constant companions and casual acquaintances. *Behavioral Ecology and Sociobiology* 29:385-389.
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- Lyrholm, T. 1998. Sperm whales, social organization and global genetic structure. Doctoral dissertation, Department of Zoology, Stockholm University, Sweden. 36 pp + enclosed publications.
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- Palacios, D.M. 1998. Bottlenose dolphins of the Galápagos Islands: an offshore ecotype with an inshore component? Page 47 (abstract) in Proceedings, XXII Reunión Internacional para el Estudio de los Mamíferos Marinos, 20-24 April 1998, Xcaret, QR, México. Sociedad Mexicana para el Estudio de los Mamíferos Marinos.
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- Palacios, D.M., P.L. Rodríguez, B.J. Brennan, and D. Day. 1998. The cetacean community around the Galápagos Islands: a preliminary look. Page 102 (abstract) in Proceedings, World Marine Mammal Science Conference, Monaco, 20-24 January 1998. The Society for Marine Mammalogy and the European Cetacean Society.

## Appendix 2

### MARINE MAMMAL REMAINS AND STRANDINGS IN THE GALÁPAGOS ISLANDS

By: Daniel M. Palacios

A comprehensive documentation of osteological remains of marine mammals found on the shores of the Galápagos Islands is presented here. Material available at the reference collection of the CDRS and other private collections in Puerto Ayora was studied. Specimens housed in collections outside the Galápagos are also documented (see Literature cited). Strandings were investigated through interviews with persons who had first-hand accounts of the events or through published descriptions. Documentation of specimens of the endemic Galápagos fur seal and sea lion has not been completed and thus information on these two species is not included here. A brief overview of this study was published by Palacios (1995b).

Fifty-three specimens have been collected between 1923 and 1994, belonging to 12 cetacean species and one exotic otariid seal. Species for which osteological material is available include: bottlenose dolphin (n=14), short-finned pilot whale (n=8), Cuvier's beaked whale (n=7), short-beaked common dolphin (n=6), pantropical spotted dolphin (n=4), South American sea lion (n=3), false killer whale (n=2), striped dolphin (n=2), sperm whale (n=2), dwarf sperm whale (n=2), ginkgo-toothed beaked whale (n=1), Risso's dolphin (n=1) and rough-toothed dolphin (n=1). The information available for each specimen is summarized in Table A1.

There is information on ten additional remains that have been observed but for which no specimens have been preserved. Some of them have been intentionally left in the field to await soft tissue decomposition and will eventually be incorporated into collections. For others, large size makes it inconvenient to transport and house them at the CDRS reference collection. Available information on these remains is presented in Table A2. Also of note is the capture of a live bottlenose dolphin off Tagus Cove, Isabela, on 20 November 1967 during an expedition by the Scripps Institution of Oceanography aboard R/V *Alpha Helix*. The specimen was used in one of the early studies of the sound transmitting characteristics of the blubber and muscle in dolphins (Norris and Harvey, 1974). The animal was dissected to look at the bony structures of the jaw and the head and no skeletal materials were preserved (K.S. Norris, *in litt.*, 11 May 1996).

Strandings of live cetaceans have been witnessed on five occasions, involving one pantropical spotted dolphin in Punta Cormorant, Floreana, in 1979; six Cuvier's beaked whales in Baltra on 1 March 1983 (Robinson *et al.*, 1983, 1984); 18 short-finned pilot whales in Puerto Baquerizo Moreno, San Cristobal, on 12 May 1984 (Ortíz-Crespo, 1986); one striped dolphin in Puerto Ayora, Santa Cruz, on 6 September 1990; and four short-finned pilot whales in Punta Suarez, Española, on 19 February 1994. According to a written account of the latter event by Ortuño (1984), the four short-finned pilot whales (one male and three females) had been swimming erratically in the shallow waters of the bay just before running aground. Once they became stranded they were pushed back to the ocean by several guides and the crew of the tour boats that were visiting the area. The animals sustained many scratches and wounds from the barnacle-encrusted rocks and it is not known whether they survived.

List of acronyms used in Table A1:

AMNH = American Museum of Natural History, New York, U.S.A.

USNM = U.S. National Museum of Natural History, Washington, D.C., U.S.A.

CNHM = Chicago Natural History Museum, Chicago, U.S.A.

MVZ = Museum of Vertebrate Zoology, University of California, Berkeley, U.S.A.

UWZS = University of Wisconsin Zoological Museum, Madison, U.S.A.

CDRS = Charles Darwin Research Station reference collection, Puerto Ayora, Galápagos.

CAS = California Academy of Sciences, San Francisco, U.S.A.

CNG = Colegio Nacional Galápagos, Puerto Ayora, Galápagos, Ecuador.

LT-FCN-UG = Laboratorio de Taxidermia, Facultad de Ciencias Naturales, Universidad de Guayaquil, Ecuador.

FEMM = Fundación Ecuatoriana para el Estudio de Mamíferos Marinos, Guayaquil, Ecuador.

## Acknowledgements

The following persons kindly provided access to collections, specimens, personal accounts, or otherwise assisted with this project: Linda Cayot (CDRS), Chantal Blanton (CDRS), Gayle Davis (CDRS), Poly Robayo (CDRS), Rodrigo Bustamante (CDRS), Elizabeth Pillaert (UWZS), Jack Nelson (Hotel Galápagos), Pdraig Whelan (CDF), Heidi M. Snell (CDRS), Fernando Felix (FEMM), Bryn Mader (AMNH), James Mead (USNM), Mao Ortuño, David Day, Gundi Schreyer, Godfrey Merlen, Gus Angermeyer, Fernando Zambrano, René Sangolquí, Mauricio Santos, Paulina Romo Leroux, Marta Romo Leroux, Mathias Espinosa and Kate Stafford.

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- Palacios, D.M. 1995b. Cetacean remains and strandings in the Galápagos Islands. Pages 27-29 in A.H. Kopelman, ed. *Proceedings of the 1995 Northeastern Regional Stranding Network Conference*, 28-30 April 1995, Riverhead, NY, USA.
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Table A1. Osteological specimens of marine mammals from the Galápagos Islands that have been catalogued or are in private collections.

Catalog #	Species	Material	Date	Locality	Notes	Collector/Source
AMNH 063986	<i>Pseudorca crassidens</i>	skull	29-Aug-1923	Baltra (South Seymour)	6 skeletons found on the beach	1923 Harrison Williams Expedition/ Beebe (1924)
AMNH 73670	<i>Pseudorca crassidens</i>	mandibles and vertebrae	11-Oct-1926	Baltra (South Seymour)	6 skeletons found on the beach	1923 Harrison Williams Expedition/ Beebe (1924)
AMNH 73666	<i>Tursiops truncatus</i>	skull	11-Oct-1926	Baltra (South Seymour)		Gregory-Beebe Expedition
USNM 258642	<i>Tursiops truncatus</i>	skull	30-Jan-1934	Post Office Bay, Floreana	beach pick-up	Walker (1981)
CNHM 51744	<i>Tursiops truncatus</i>	skull		1941 Academy Bay, Santa Cruz		Leon Mandel Expedition/ Hershkovitz (1963)
MVZ 125479	<i>Tursiops truncatus</i>	skull	19-Oct-1957	San Cristobal	beach pick-up	Walker (1981)
UWZS 27309	<i>Tursiops truncatus</i>	skull and skeleton	15-May-1977	N Caleta Negra, Isabela		R.W. Tindle
CDRS V-944	<i>Tursiops truncatus</i>	skull	2-May-1977	Playa Negra, Floreana		F. Trillmich, female
CDRS V-945	<i>Tursiops truncatus</i>	skull	2-May-1977	Playa Negra, Floreana		F. Trillmich, female
CDRS V-946	<i>Tursiops truncatus</i>	skull	10-May-1986	Mosquera		D. Day
CDRS V-947	<i>Tursiops truncatus</i>	skull				
CDRS V-948	<i>Tursiops truncatus</i>	skull				
CDRS V-950	<i>Tursiops truncatus</i>	skull and skeleton	2-Sep-1984	Urvina Bay, Isabela		C. Valle and I. Stupakoff
CDRS V-951	<i>Tursiops truncatus</i>	skull and skeleton				

Table A1. Continued.

Catalog #	Species	Material	Date	Locality	Notes	Collector/Source
CDRS V-1183	<i>Tursiops truncatus</i>	skull and skeleton	2-Sep-1993	Punta Estrada, Santa Cruz	2.79-m female	R. Sangolquí/ Lettevall et al. (1993)
Private collection	<i>Tursiops truncatus</i>	skull and skeleton		Santa Cruz (?)		G. Angermeyer, Puerto Ayora
CAS 12889	<i>Steno bredanensis</i>	skull and skeleton	21-Feb-1964	Tortuga Bay, Santa Cruz	beach pick-up	1964 Galápagos International Project/ Orr (1965)
Private collection	<i>Physeter macrocephalus</i>	skull and skeleton		1964 Punta Rocafuerte, Santa Cruz		G. Angermeyer, Puerto Ayora
Private collection	<i>Physeter macrocephalus</i>	skull only		1970 Genovesa		J. Nelson, Hotel Galápagos, Puerto Ayora
CDRS V-905	<i>Mesoplodon ginkgodens</i>	2 teeth	15-Jun-1970	Bahia Darwin, Genovesa	3.60-m male	Tj. de Vries/ Palacios (1996)
Private collection	<i>Globicephala macrorhynchus</i>	skull		1960-1970 Punta Rocafuerte, Santa Cruz		J. Nelson, Hotel Galápagos, Puerto Ayora
CDRS V-1018	<i>Globicephala macrorhynchus</i>	skull	Mar. 1975	N Santiago		P. Pritchard
CDRS V-1016	<i>Globicephala macrorhynchus</i>	skull	10-May-1986	Mosquera		
CDRS V-1097	<i>Globicephala macrorhynchus</i>	lower jaw and bones				
CDRS V-1017	<i>Globicephala macrorhynchus</i>	lower jaw and bones				
CDRS V-1019	<i>Globicephala macrorhynchus</i>	skull				
Private collection	<i>Globicephala macrorhynchus</i>	skull				M. Santos and P. Romoleroux, Puerto Ayora
Private collection	<i>Globicephala macrorhynchus</i>	skull		Santa Cruz (?)		G. Angermeyer, Puerto Ayora

Table A1. Continued.

Catalog #	Species	Material	Date	Locality	Notes	Collector/Source
CDRS V-926	<i>Otaria byronia</i>	skull	10-Oct-1973	Cabo Ibbetson, Pinta	adult male	Wellington and de Vries (1976)
UWZS 31500	<i>Otaria byronia</i>	skull	24-Nov-1992	Punta Núñez, Santa Cruz	adult male	Merlen (1993)
CDRS V-1166	<i>Otaria byronia</i>	skull and partial skeleton	3-Mar-1993	Cabo Ibbetson, Pinta		F. Trillmich
CDRS V-857	<i>Stenella attenuata</i>	skull	1-Mar-1975	NW San Cristobal	previosuly mis-identified as <i>D. delphis</i>	J. Webb/ Palacios (1995a)
CDRS V-858	<i>Stenella attenuata</i>	skull	1-Mar-1975	NW San Cristobal	previosuly mis-identified as <i>D. delphis</i>	J. Webb/ Palacios (1995a)
CDRS V-859	<i>Stenella attenuata</i>	skull	1-Mar-1975	NW San Cristobal	previosuly mis-identified as <i>D. delphis</i>	J. Webb/ Palacios (1995a)
Private collection	<i>Stenella attenuata</i>	skull and skeleton	1979	Punta Cormorant, Floreana	male, live-stranded	D. Day and G. Schreyer, Puerto Ayora
CDRS V- 949	<i>Delphinus delphis</i> (?)	skeleton only	Jan. 1975	Punta Rocafuerte, Santa Cruz		F.C. Angermeyer
CDRS V-591	<i>Delphinus delphis</i>	skull	Nov. 1982	Tortuga Bay, Santa Cruz		E. Andrade and F. Morán
CDRS V-1182	<i>Delphinus delphis</i>	skull and skeleton	7-Nov-1993	Cabo Douglas, Fernandina		G. Merlen
CDRS HMS-Dd	<i>Delphinus delphis</i>	skull	Mar. 1994	Gardner Bay, Española		H.M. Snell
Private collection	<i>Delphinus delphis</i>	skull and skeleton		Santa Cruz (?)		G. Angermeyer, Puerto Ayora
Private collection	<i>Delphinus delphis</i>	skull		Gardner Bay, Española		D. Day and G. Schreyer, Puerto Ayora
CDRS V-904	<i>Ziphius cavirostris</i>	skull	1-Mar-1983	Baltra Harbor, Baltra	mass-stranded	Robinson et al. (1983, 1984)

Table A1. Continued.

Catalog #	Species	Material	Date	Locality	Notes	Collector/Source
CDRS V-1020	<i>Ziphius cavirostris</i>	skull	1-Mar-1983	Baltra Harbor, Baltra	mass-stranded	Robinson et al. (1983, 1984)
CNG	<i>Ziphius cavirostris</i>	skull and skeleton		1992 Tortuga Bay, Santa Cruz	mounted at CNG	D. Day and G. Merlen
CDRS #?	<i>Ziphius cavirostris</i>	skull	4-Mar-1994	found at sea, 52 km WNW of Cabo Berkeley, Isabela	4.2-m female	Palacios et al. (1994a,b)
Private collection	<i>Ziphius cavirostris</i>	skull				J. Nelson, Hotel Galápagos, Puerto Ayora
Private collection	<i>Ziphius cavirostris</i>	skull				G. Ribadeneira and M. Romoleroux
Private collection	<i>Ziphius cavirostris</i>	skull and skeleton		Santa Cruz (?)		G. Angermeyer, Puerto Ayora
LT-FCN-UG	<i>Kogia simus</i>	skull and skeleton	Mar. 1990	Quinta Playa, Isabela		E. Moreira and F. Félix, FEMM/ Muñoz-Hincapié et al. (1998)
Private collection	<i>Kogia simus</i>	skull		N Santa Cruz		G. Angermeyer, Puerto Ayora. Muñoz-Hincapié et al. (1998)
UWZS 31501	<i>Stenella coeruleoalba</i>	partial skull and skeleton	6-Sep-1990	Puerto Ayora, Santa Cruz	2.11-m female, live-stranded	A. Izurieta and P. Whelan/ Van Waerebeek et al. (1998)
Private collection	<i>Stenella coeruleoalba</i>	skull	Jan. 1992	Tortuga Bay, Santa Cruz		F. Zambrano, Puerto Ayora/ Van Waerebeek et al. (1998)
Private collection	<i>Grampus griseus</i>	skull		Santa Cruz (?)		G. Angermeyer, Puerto Ayora

### Appendix 3

## MORPHOMETRIC AND MERISTIC DATA FOR SKULLS OF FOUR DOLPHIN SPECIES FROM THE GALÁPAGOS

By: Daniel M. Palacios

Measurements of morphometric and meristic characters were performed on 17 dolphin skulls from the Galápagos Islands, as part of a study documenting marine mammal osteological collections in the archipelago (see Appendix 2). These skulls belong to the following four species: bottlenose dolphin (n=8), pantropical spotted dolphin (n=4), short-beaked common dolphin (n=4) and striped dolphin (n=1).

List of specimens measured (see Table A1 for collection information):

Catalog No.	Species	Sex	M-Pm*
CDRS V-944	<i>Tursiops truncatus</i>	female (?)	
CDRS V-945	<i>Tursiops truncatus</i>	female (?)	
CDRS V-946	<i>Tursiops truncatus</i>		
CDRS V-947	<i>Tursiops truncatus</i>		
CDRS V-948	<i>Tursiops truncatus</i>		
CDRS V-950	<i>Tursiops truncatus</i>		
CDRS V-951	<i>Tursiops truncatus</i>		
CDRS V-1183	<i>Tursiops truncatus</i>	female	
CDRS V-857	<i>Stenella attenuata</i>		
CDRS V-858	<i>Stenella attenuata</i>		
CDRS V-859	<i>Stenella attenuata</i>		
DD&GS Sa	<i>Stenella attenuata</i>	male (?)	no
DD&GS Dd	<i>Delphinus delphis</i>		yes
CDRS V-591	<i>Delphinus delphis</i>		
CDRS V-1182	<i>Delphinus delphis</i>		yes
CDRS HMS-Dd	<i>Delphinus delphis</i>		yes
FZ Sc	<i>Stenella coeruleoalba</i>		no (?)

\*M-Pm = distal fusion of maxillaries with premaxillaries (only for *Stenella attenuata*, *S. coeruleoalba* and *Delphinus delphis*).

List of acronyms used:

CDRS = Charles Darwin Research Station reference collection, Puerto Ayora, Galápagos.  
 DD&GS = private collection of David Day and Gundi Schreyer, Puerto Ayora, Galápagos.  
 FZ = private collection of Fernando Zambrano, Puerto Ayora, Galápagos.

A total of thirty-six characters were assessed for each skull. Thirty-five of these characters follow Schnell *et al.* (1985) and Van Waerebeek *et al.* (1990) (Nos. 1-16, 19-22, 24-38), and one character was added (No. 39: “width of occipital condyles”). Whenever possible measurements were recorded to the nearest 0.1 mm with dial calipers (Nos. 4-8, 15-27, 34-35,

37-39), and others were taken to the nearest 0.5 mm using a measuring tape (Nos. 1-3, 9-14, 28, 33, 36). Caution needs to be exercised when interpreting these data quantitatively, however, as many of the skulls were severely damaged or worn out (the skulls have been collected over a period of many years, most of them after being exposed to the surf, the rocks and the sun for considerable time. Some of them have also spent time buried to let the soft tissues decompose and be removed by scavengers, resulting in some deterioration of the bony tissue). For skulls with incomplete or absent tooth rows, the alveoli were counted and these are given as tooth counts. However, some skulls were so worn out (or broken at the tips) that not all the alveoli were evident. In these cases the maximum number of alveoli that could be counted is given (with a + symbol indicating that more teeth were present), and whenever possible an estimate of the total number of teeth per row is given in parenthesis ( ). When bones were missing or were broken, but an estimate of the character could still be made, it is given in square brackets [ ]. Character No. 3, “length of rostrum from pterygoid”, often involved making this estimation. The measurements are presented in Tables A3, A4 and A5.

External measurements are also available for specimen CDRS V-1183, a bottlenose dolphin (Lettevall *et al.*, 1993), and for a male short-beaked common dolphin that was found on 19 December 1994 on Punta Cormorant, Floreana (data courtesy of D. Day), but that has not been collected (see Table A2). All measurements are in cm:

<b>Measurement</b>	<b>CDRS V-1183</b>	<b><i>Delphinus delphis</i> (in the field)</b>
Total length	279	214
Flipper width	17.8	9.3
Fluke width	58.4	49 (missing c. 1 cm at tip)
Fluke notch to anus	78.7	61
Blow hole to base of dorsal fin	87.6	
Umbilicus to anus	70.5	
Width between base of flippers	25.4	
Center of eye to center of ear hole	7.6	
Anus to penis	N/A	17.5
Rear edge dorsal fin to fluke notch		90
Rear edge dorsal fin to snout tip		128
Height of dorsal fin		15.5
Base of dorsal fin		36-43
Leading edge of flipper (curve)		31 (29 straight)
No. teeth, lower right jaw	23	43
No. teeth, upper right jaw	23	46

Measurement of metric and non-metric characters in marine mammal skulls is useful in studies of life history, geographic variation and sexual dimorphism. The sample presented here could be augmented by extending the study to other specimens that are available, as documented in Appendix 2.

## Literature cited

- Lettevall, E., L. Galley, D.M. Palacios, and L. Urian. 1993. A stranded bottlenose dolphin (*Tursiops truncatus*) on Isla Santa Cruz, Galápagos Islands. Internal Report to the National Park Service and the Charles Darwin Research Station. Puerto Ayora, Isla Santa Cruz, Is. Galápagos, Ecuador, 14 September 1993. 6 pp.
- Schnell, G.D., M.E. Douglas, and D.J. Hough. 1985. Sexual dimorphism in spotted dolphins (*Stenella attenuata*) in the eastern tropical Pacific Ocean. *Marine Mammal Science* 1(1):1-14.
- Van Waerebeek, K., J.C. Reyes, A.J. Read, and J.F. McKinnon. 1990. Preliminary observations of bottlenose dolphins from the Pacific coast of South America. Pages 143-154 in S. Leatherwood and R. Reeves, eds. *The bottlenose dolphin*. Academic Press, San Diego. 653pp.

Table A2. Marine mammal remains for which no specimens are available.

<b>Species</b>	<b>Date</b>	<b>Locality</b>	<b>Notes</b>	<b>Observer/Source</b>
<i>Balaenoptera</i> sp.	1971	Academy Bay, Santa Cruz	female with unborn fetus	MacFarland (1977)
<i>Grampus griseus</i>	1976-1978	Gardner Bay, Española	specimen collected for CDRS but apparently lost	D. Day
<i>Globicephala macrorhynchus</i>	12-May-84	Puerto Baquerizo Moreno, San Cristobal	group of 18 animals; remains were incinerated	Ortíz-Crespo (1986)
<i>Globicephala macrorhynchus</i>	Apr-88	1km off Punta Moreno, Isabela	male	Le Boeuf et al. (1988)
<i>Physeter macrocephalus</i>	1989	W Punta Espinosa, Fernandina	skull and scattered bones still in the field	E. Pillaert and M. Ortuño
<i>Physeter macrocephalus</i>	26-Sep-90	Academy Bay, Santa Cruz	teeth collected by G. Merlen; remains still in the field	M. Ortuño
<i>Delphinus delphis</i>	19-Dec-94	Punta Cormorant, Floreana	2.14-m male; teeth collected by D. Day	D. Day
<i>Balaenoptera edeni</i>	Jun-95	Rabida	male	G. Merlen
<i>Ziphius cavirostris</i>	Feb-96	Santa Cruz	young female	D. Day
<i>Stenella attenuata</i>	1996	Santa Cruz		D. Day

Table A3. Cranial measurements (in mm) and meristics of eight skulls of *Tursiops truncatus* from the Galápagos Islands, Ecuador.

CHARACTER	CDRS V-944	CDRS V-945	CDRS V-946	CDRS V-947	CDRS V-948	CDRS V-950	CDRS V-951	CDRS V-1183
1. Condylbasal length	514.0	492.0	450.0	467.0	454.0	468.0	509.0	518.0
2. Length of rostrum (from base)	293.0	274.0	243.0	258.0	250.0	264.0	287.0	286.0
3. Length of rostrum (from pterygoid)	343.0	[315]	[296]	[310-320]	[305]	314.0	[350-360]	362.0
4. Width of rostrum (at base)	142.4	143.7	129.3	-	116.9	123.3	148.6	130.0
5. Width of rostrum (at 1/4 length)	110.0	101.2	98.3	-	89.0	96.6	103.1	97.4
6. Width of rostrum (at 1/2 length)	89.8	82.5	82.4	-	74.5	80.5	85.1	81.1
7. Width of premaxilla (at 1/2 length)	53.4	41.5	44.3	-	47.1	48.2	48.8	46.2
8. Width of rostrum (at 3/4 length)	70.0	62.5	66.8	-	55.9	62.0	65.8	58.8
9. Preorbital width	231.0	215.0	216.0	-	192.0	204.0	235.0	213.0
10. Postorbital width	259.0	250.0	249.0	220.0	223.0	234.0	[256]	270.0
11. Skull width (at zygomatic process)	257.0	244.0	232.0	220.0	208.0	225.0	256.0	205.0
12. Skull width (at parietals)	205.0	203.0	185.0	189.0	182.0	195.0	208.0	200.0
13. Height of braincase	160.0	155.0	160.0	155.0	145.0	135.0	150.0	135.0
14. Length of braincase	145.5	147.6	140.5	146.0	138.5	143.0	146.0	162.0
15. Maximum width of premaxilla	91.1	91.5	92.1	-	83.4	84.8	100.9	88.9
16. Width of external nares	60.8	59.2	56.1	-	52.6	56.3	58.1	56.8
19. Length of temporal fossa	121.0	105.8	100.6	98.2	97.6	100.0	117.8+	110.8
20. Width of temporal fossa	86.4	77.1	79.1	71.8	66.8	71.6	81.6	82.7
21. Orbital length	68.8	65.7	64.5	64.1	60.5	61.8	53.7	69.8
22. Length of antorbital process	58.4	60.7	60.5	-	49.1	57.5	-	66.4
24. Width of internal nares	78.0	77.4	75.1	68.9	67.5	68.9	-	74.9
25. Length of left tympanic cavity	62.6	64.6	65.2	57.9	56.7	60.6	70.4	73.4
26. Length of right tympanic cavity	66.9	65.5	68.0	57.1	55.7	63.7	-	72.0
27. Width at pterygoid sutures	86.9	82.0	70.0	70.4	74.4	73.4	66.0	89.4
28. Length of upper toothrow	242.5	225.2	196.0	217.0	200.0	220.0	237.0	245.0
29. No. of teeth (upper left toothrow)	23.0	25.0	20+ (21)	20+ (22)	22.0	21+ (22)	19+	24.0
30. No. of teeth (upper right toothrow)	23.0	24.0	19+ (21)	19+ (22)	21.0	21+ (22)	21+	23.0
31. No. of teeth (lower left toothrow)	-	-	-	-	-	-	-	23.0
32. No. of teeth (lower right toothrow)	-	-	-	-	19+ (20)	-	-	23.0
33. Length of lower toothrow	-	-	-	-	193.0	-	-	-
34. Height of ramus	-	-	-	-	81.2	-	-	93.4
35. Tooth width	-	-	-	-	-	-	-	6.2
36. Length of ramus	-	-	-	-	379.0	-	-	445.0
37. Mandibular condyle width	-	-	-	-	23.2	-	-	24.2
38. Maximum width of palatine	62.5	61.0	57.2	-	49.2	51.6	57.7	41.5
39. Width of occipital condyles	111.8	108.4	107.0	94.7	97.9	92.0	97.2	109.8

Table A4. Cranial measurements (in mm) and meristics of four specimens of *Stenella attenuata* from the Galápagos Islands, Ecuador.

CHARACTER	CDRS V-857	CDRS V-858	CDRS V-859	DD&GS Sa
1. Condylbasal length	390.0	380.0	363.0	374.5+
2. Length of rostrum (from base)	228.0	224.0	212.0	208+
3. Length of rostrum (from pterygoid)	284.0	260.0	256.5	261+
4. Width of rostrum (at base)	85.4	84.3	81.2	87.2
5. Width of rostrum (at 1/4 length)	59.9	62.1	64.6	63.5
6. Width of rostrum (at 1/2 length)	46.6	47.7	46.6	49.5
7. Width of premaxilla (at 1/2 length)	25.8	28.7	26.1	23.1
8. Width of rostrum (at 3/4 length)	39.4	35.5	38.8	40.1
9. Preorbital width	150.7	151.6	150.7	156.2
10. Postorbital width	165.0	163.5	146.5	168.0
11. Skull width (at zygomatic process)	160.0	157.2	153.4	167.0
12. Skull width (at parietals)	160.0	144.5	135.2	140.0
13. Height of braincase	119.3	122.5	118.5	101.0
14. Length of braincase	105.0	109.2	107.2	114.0
15. Maximum width of premaxilla	162.9	68.2	67.9	70.9
16. Width of external nares	41.6	41.9	41.5	43.0
19. Length of temporal fossa	58.8	70.0	61.9	65.5
20. Width of temporal fossa	49.8	54.2	51.9	58.5
21. Orbital length	50.5	47.5	46.6	51.3
22. Length of antorbital process	39.9	39.9	39.9	38.1
24. Width of internal nares	48.9	45.6	46.5	47.2
25. Length of left tympanic cavity	45.5	50.0	47.9	45.3
26. Length of right tympanic cavity	47.7	47.1	47.1	45.7
27. Width at pterygoid sutures	47.9	43.9	42.0	49.7
28. Length of upper toothrow	206.0	195.0	182+	176+
29. No. of teeth (upper left toothrow)	35+ (45)	40+	35+	35+
30. No. of teeth (upper right toothrow)	45.0	40.0	30+	27+
31. No. of teeth (lower left toothrow)	41.0	41.0	-	39.0
32. No. of teeth (lower right toothrow)	40.0	38+ (41)	41+ (42)	40.0
33. Length of lower toothrow	19.6	204.0	189.0	200.0
34. Height of ramus	55.9	56.0	58.6	55.8
35. Tooth width	2.5	-	-	-
36. Length of ramus	337.0	330.0	316.5	345.0
37. Mandibular condyle width	12.8	13.3	13.0	13.3
38. Maximum width of palatine	33.4	42.8	35.5	33.0
39. Width of occipital condyles	79.8	68.2	77.4	93.7

Table A5. Cranial measurements (in mm) and meristics of four specimens of *Delphinus delphis* and one of *S. coeruleoalba* from the Galápagos Islands, Ecuador.

CHARACTER	CDRS	CDRS	CDRS	DD&GS	FZ
	V-591	V-1182	HMS-Dd	Dd	Sc
1. Condylbasal length	340.0	442.0	458+	375.0	386.8
2. Length of rostrum (from base)	192.0	270.0	273+	214.0	208.5+
3. Length of rostrum (from pterygoid)	235.0	321.0	320.0	254.0	273.5
4. Width of rostrum (at base)	75.7	87.5	95.4	93.6	109.3
5. Width of rostrum (at 1/4 length)	50.0	62.1	64.8	61.1	73.0
6. Width of rostrum (at 1/2 length)	40.7	53.3	54.0	50.7	64.5
7. Width of premaxilla (at 1/2 length)	20.9	23.0	23.1	23.1	30.0
8. Width of rostrum (at 3/4 length)	30.1	39.7	42.6	40.8	59.6
9. Preorbital width	133.8	179.0	171.0	168.0	182.0
10. Postorbital width	147.5	169.0	190.0	185.0	211.0
11. Skull width (at zygomatic process)	135.5	164.0	180.0	164.0	215.0
12. Skull width (at parietals)	136.6	160.0	200.0	170.0	177.0
13. Height of braincase	110.8	117.5	123.0	114.6	132.8
14. Length of braincase	104.5	114.0	110.8	110.1	117.0
15. Maximum width of premaxilla	62.1	73.5	72.1	75.0	89.3
16. Width of external nares	38.1	49.5	42.8	46.1	43.6
19. Length of temporal fossa	49.3	60.3	74.2	61.2	64.5
20. Width of temporal fossa	34.7	53.3	49.6	51.0	50.2
21. Orbital length	46.6	51.6	54.5	48.5	56.0
22. Length of antorbital process	32.8	44.4	39.5	46.8	58.3
24. Width of internal nares	40.0	56.1	36.4	52.5	58.0
25. Length of left tympanic cavity	42.0	46.3	45.0	47.3	53.8
26. Length of right tympanic cavity	41.0	47.1	44.0	49.0	50.9
27. Width at pterygoid sutures	37.3	53.5	55.5	49.8	60.7
28. Length of upper toothrow	164.0	230.0	-	153+	173+
29. No. of teeth (upper left toothrow)	40+ (50)	43+	47+	25+	30+ (35)
30. No. of teeth (upper right toothrow)	40+ (50)	46+ (48)	46+	-	24+
31. No. of teeth (lower left toothrow)	39+ (45)	48.0	-	39+	-
32. No. of teeth (lower right toothrow)	40+ (47)	48+ (50)	-	-	-
33. Length of lower toothrow	150.0	232.0	-	180+	-
34. Height of ramus	50.6	64.1	-	66.7	-
35. Tooth width	2.3	2.9	-	-	-
36. Length of ramus	284.0	387+	-	344+	-
37. Mandibular condyle width	12.6	15.5	-	16.3	-
38. Maximum width of palatine	25.0	21.8	26.7	25.1	40.0
39. Width of occipital condyles	73.2	90.6	82.5	87.6	87.6